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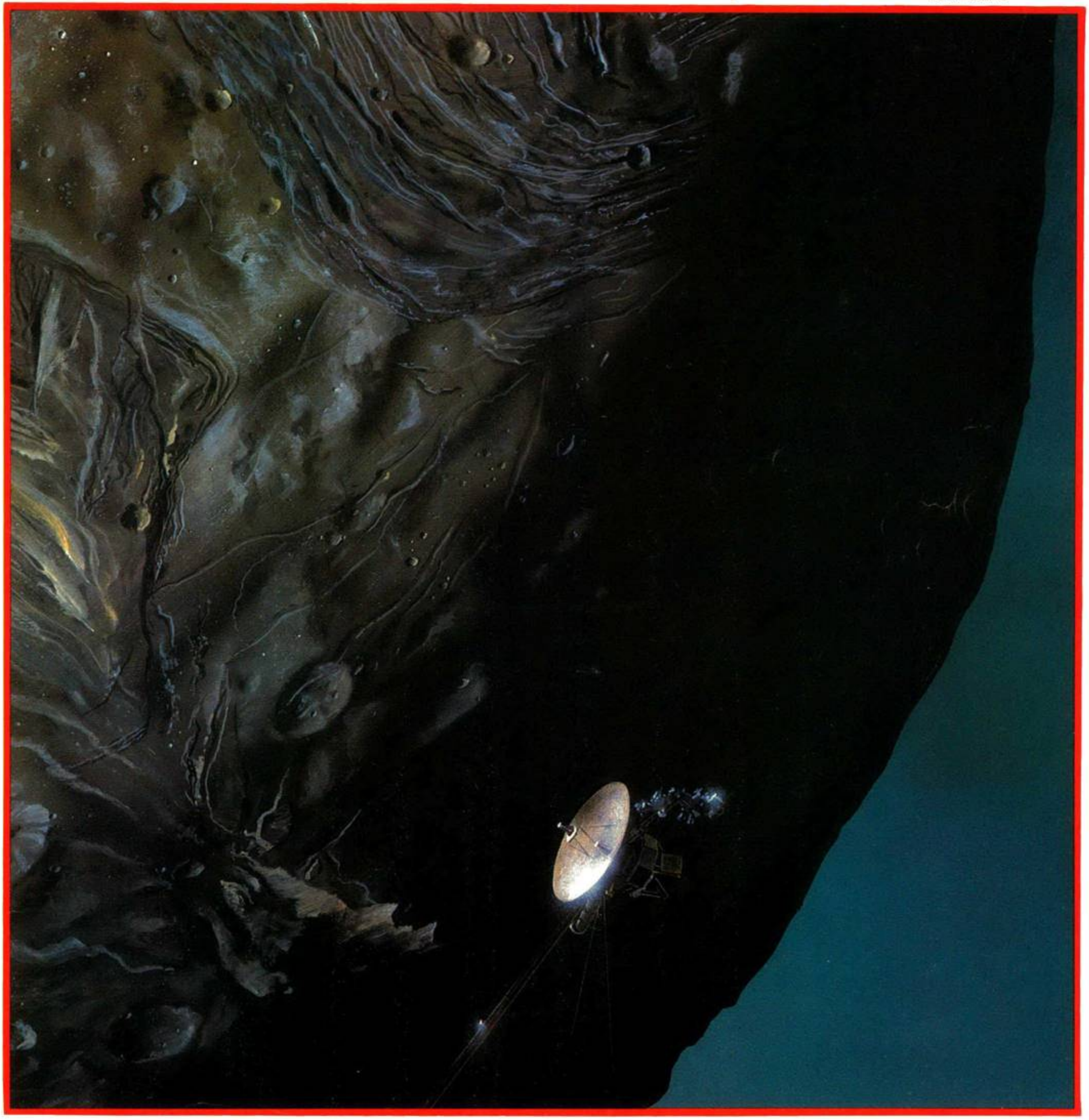

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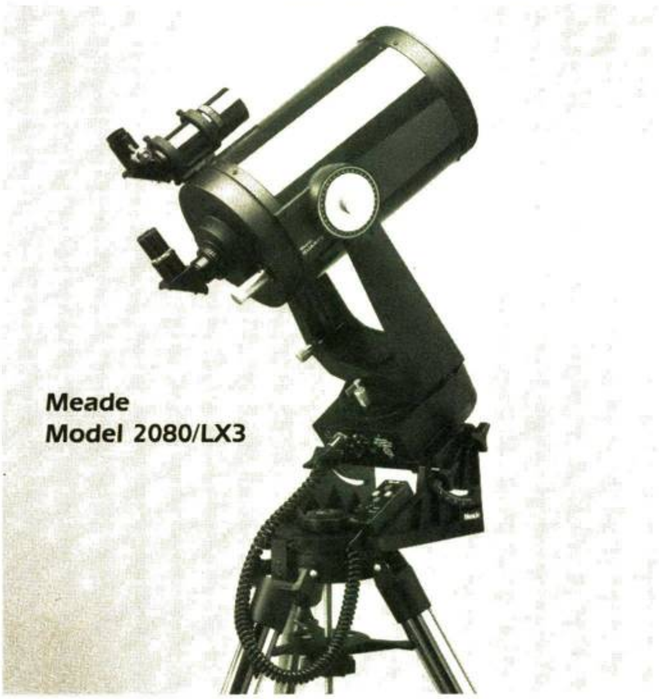

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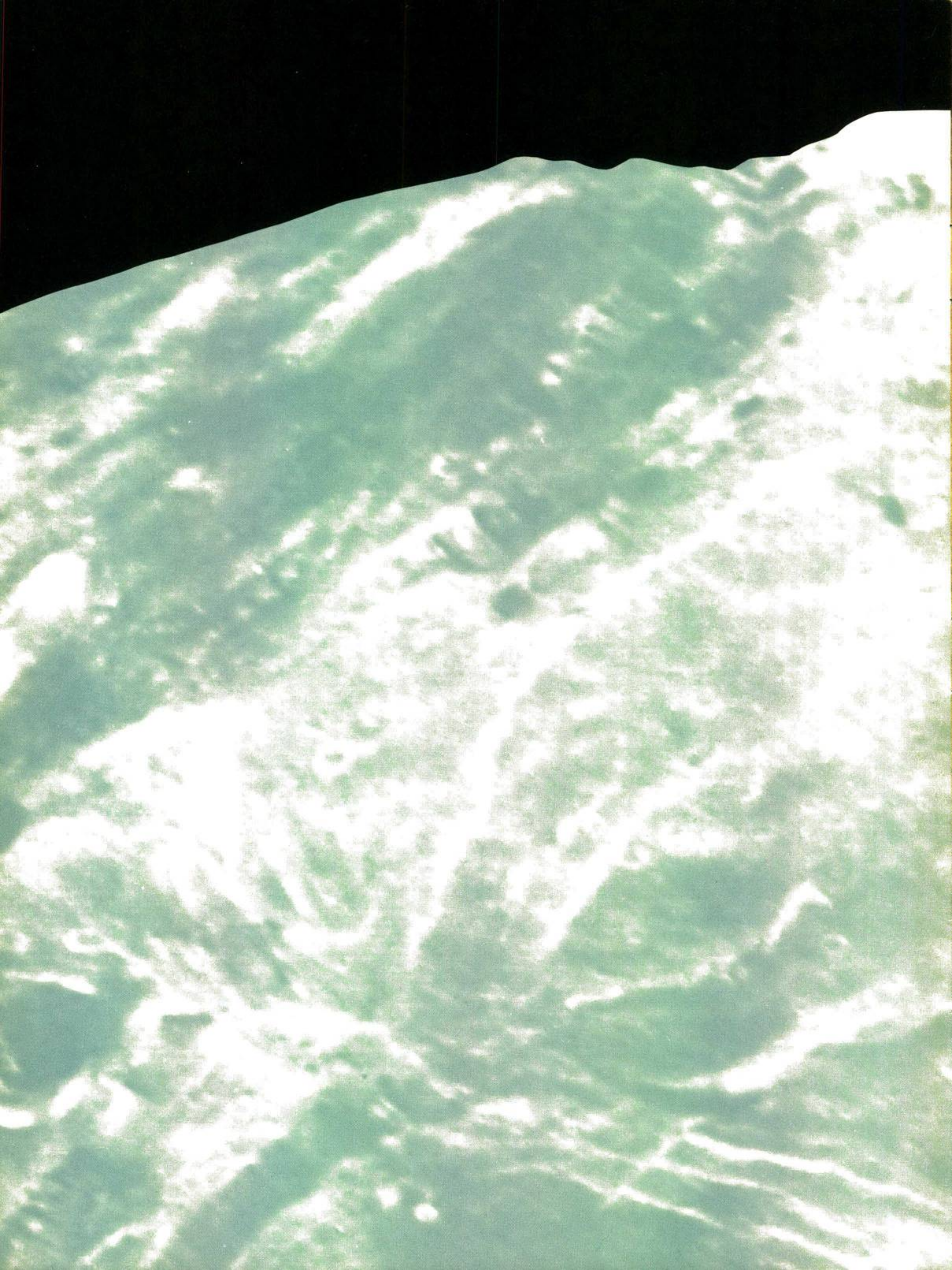

ASTRONOMY

Vol. 14, No. 5 May 1986

The World's Most Beautiful Astronomy Maga

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Canadian Newsstand Dist.
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Cover: From a scant 19,000 kilometers above the surface of Miranda, Uranus' innermost major moon, cameras aboard the Voyager 2 space probe image the strange topography of a world far from home. Painting by Michael Carroll. These pages: Radioed a distance of three billion kilometers to the huge receivers of NASA's Deep Space Network and reconstructed bit by bit and pixel by pixel, this image of Miranda reveals a bewildering variety of fractures, grooves, and craters. JPL/NASA photo P-29513.

ASTRONOMY (ISSN 0091-6358) is published monthly by AstroMedia, a division of Kalmbach Publishing Co., 625 E. St. Paul Ave., P.O. Box 92788, Milwaukee, WI 53202.

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Second class postage paid at Milwaukee, WI and additional mailing offices. POSTMASTER: Send address changes to ASTRONOMY, P.O. Box 92788, Milwaukee, WI 53202. Questions about subscriptions and product orders: (414) 272-2060 weekdays, 8:30am - 4:45pm. Allow six to eight weeks for new subscriptions and changes of address. New subscriptions start with current issue. Subscription price: 1 year, $21.00. All foreign: add $5.00 per year; please remit in U.S. funds. Send editorial and business inquiries and submissions to the address above. Telephone: (414) 276-2689. Not responsible for unsolicited materials. ASTRONOMY is indexed in *The Reader's Guide to Periodical Literature*. Microfilms of ASTRONOMY available from University Microfilms, Inc., 300 N. Zeeb Rd., Ann Arbor, MI 48106 and Bell & Howell Company, Old Mansfield Rd., Wooster, OH 46691. Printed in the U.S.A.

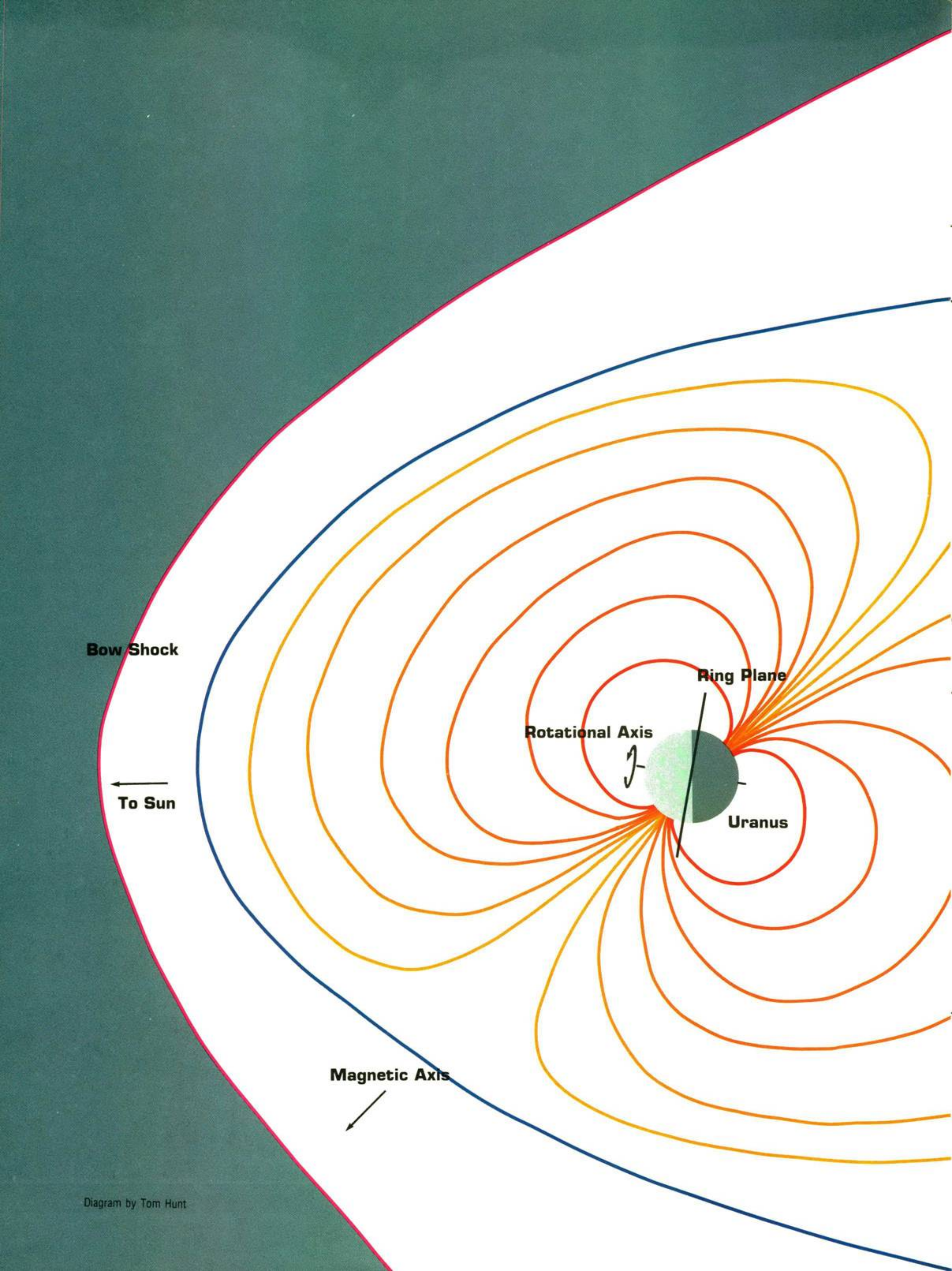

Bow Shock
Ring Plane
Rotational Axis
To Sun
Uranus
Magnetic Axis

Diagram by Tom Hunt

VOYAGER:
Discovery at Uranus

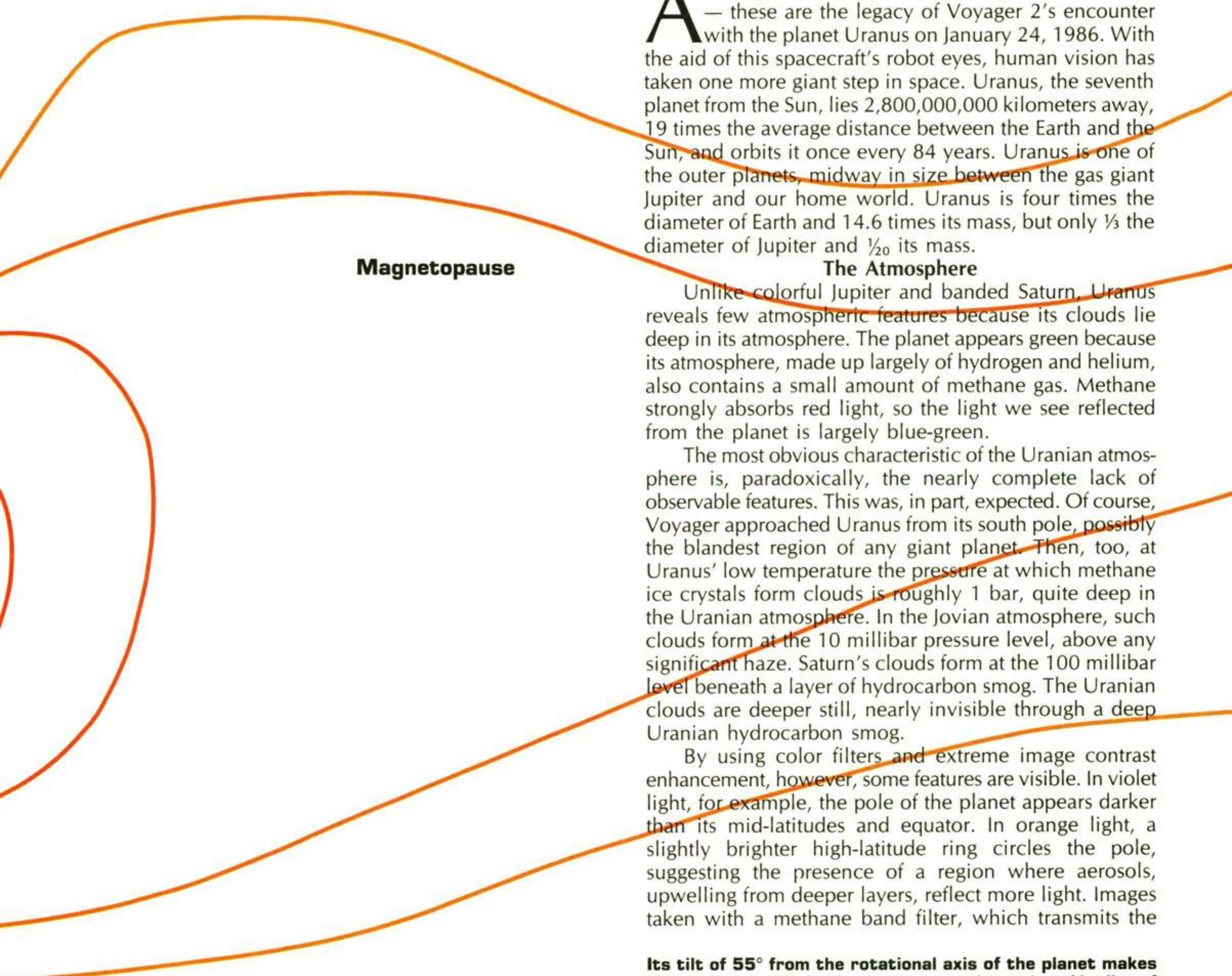
A blue-green atmosphere, ten rings, fifteen moons — these are the legacy of Voyager 2's encounter with the planet Uranus on January 24, 1986. With the aid of this spacecraft's robot eyes, human vision has taken one more giant step in space. Uranus, the seventh planet from the Sun, lies 2,800,000,000 kilometers away, 19 times the average distance between the Earth and the Sun, and orbits it once every 84 years. Uranus is one of the outer planets, midway in size between the gas giant Jupiter and our home world. Uranus is four times the diameter of Earth and 14.6 times its mass, but only ⅓ the diameter of Jupiter and $\frac{1}{20}$ its mass.

The Atmosphere

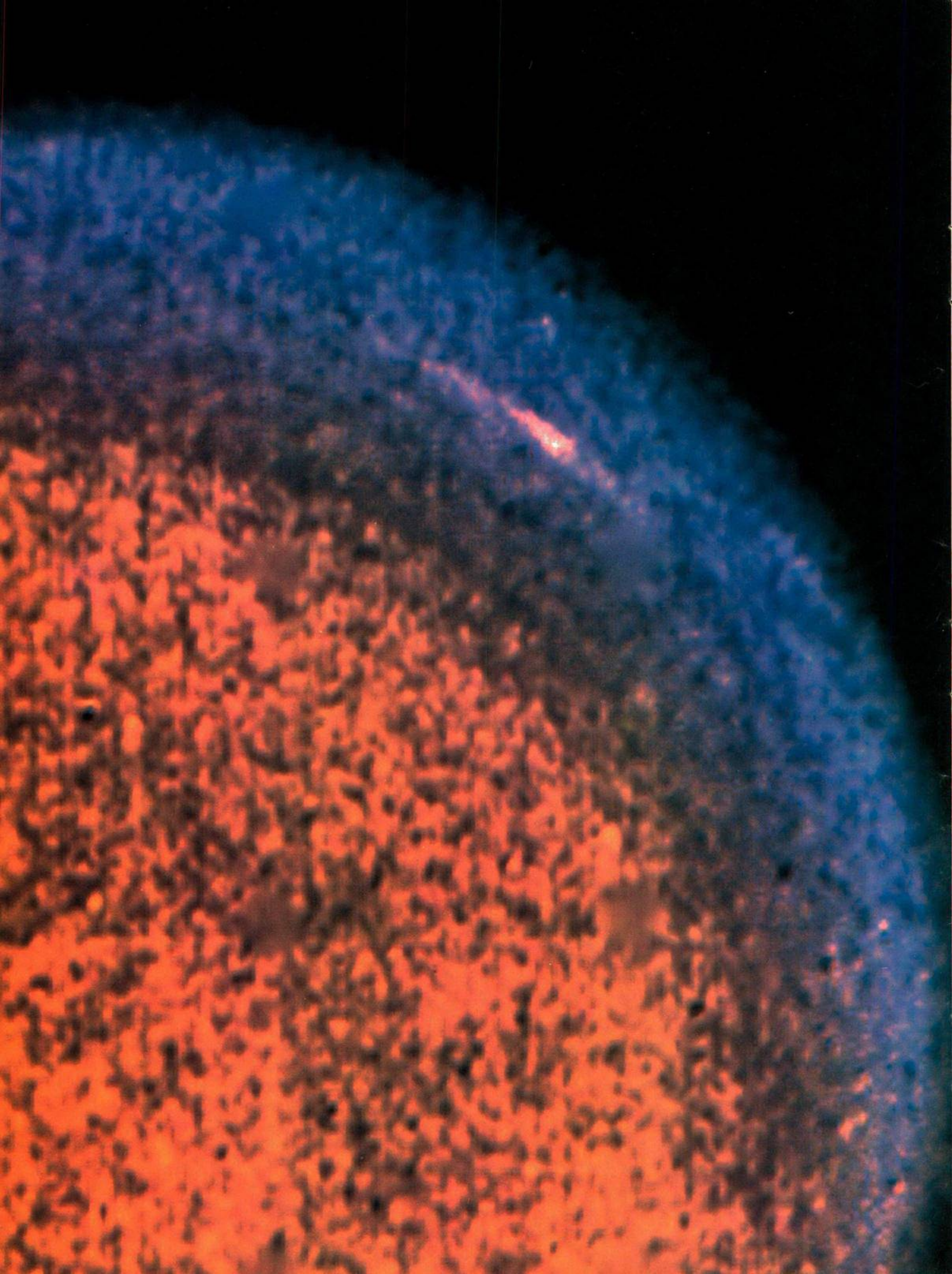
Unlike colorful Jupiter and banded Saturn, Uranus reveals few atmospheric features because its clouds lie deep in its atmosphere. The planet appears green because its atmosphere, made up largely of hydrogen and helium, also contains a small amount of methane gas. Methane strongly absorbs red light, so the light we see reflected from the planet is largely blue-green.

The most obvious characteristic of the Uranian atmosphere is, paradoxically, the nearly complete lack of observable features. This was, in part, expected. Of course, Voyager approached Uranus from its south pole, possibly the blandest region of any giant planet. Then, too, at Uranus' low temperature the pressure at which methane ice crystals form clouds is roughly 1 bar, quite deep in the Uranian atmosphere. In the Jovian atmosphere, such clouds form at the 10 millibar pressure level, above any significant haze. Saturn's clouds form at the 100 millibar level beneath a layer of hydrocarbon smog. The Uranian clouds are deeper still, nearly invisible through a deep Uranian hydrocarbon smog.

By using color filters and extreme image contrast enhancement, however, some features are visible. In violet light, for example, the pole of the planet appears darker than its mid-latitudes and equator. In orange light, a slightly brighter high-latitude ring circles the pole, suggesting the presence of a region where aerosols, upwelling from deeper layers, reflect more light. Images taken with a methane band filter, which transmits the



Its tilt of 55° from the rotational axis of the planet makes Uranus' magnetic field unique among the explored bodies of the solar system. By a wide margin, no other planet shows so great a disparity between its rotational and magnetic poles.



> **"Only when we get to Neptune will we be able to say where Uranus fits into the outer planets."**
> — Gary Hunt

wavelengths that methane absorbs, showed a strong limb brightening effect testifying to aerosols high in the Uranian atmosphere.

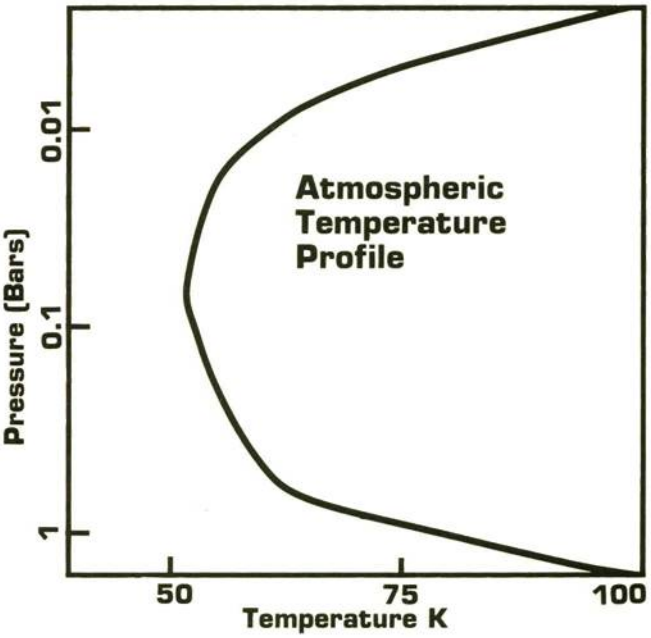
Although not indicative of the true rotation of the bulk planet, Voyager images showed that clouds at different latitudes move around the planet at different rates. Those at 40° latitude return to the same place in 16.0 hours, while those nearer the equator at 27° latitude take 16.9 hours. A 4,000-kilometer-long cloud near 33° south latitude, much like the white clouds on Jupiter and Saturn, testified to the presence of convection that can raise aerosols high into the stratosphere and wind shear that pulls this "tracer" material downwind.

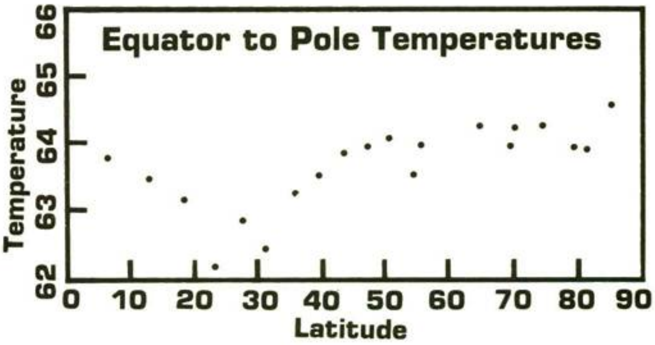
On the face of it, the Uranian poles should be hot and the planet's equator should be cold because of the distribution of sunlight. Over an entire orbit, the poles receive more sunlight than the equator and the massive atmosphere cannot radiate the heat away fast enough. The pole, therefore, should have been about 6 degrees Kelvin warmer than the equator. The infrared instrument scanned Uranus from pole to equator seeking to confirm this expected distribution of temperatures.

Instead, the planet proved to be almost uniform in temperature. At the atmospheric level it measured, the infrared spectrometer instrument (IRIS) found that most of Uranus is 64 degrees Kelvin. However, a band between 10° and 40° latitude is some 2 degrees Kelvin cooler. Whether this overall thermal uniformity results from primordial heat still escaping from the interior — Uranus radiates about 1.27 times as much energy as it receives from the Sun — or some not yet understood way of redistributing the received solar radiation energy — what the Voyager meteorologists call a "refrigerator mechanism" — remains an open question.

The best and deepest depth profile of the Uranian atmosphere will eventually come from the radio occultation experiment. Full analysis of the radio signals will characterize the atmosphere between 100 microbars pressure to greater than 1 bar. Preliminary results, however, give a pressure- temperature profile from the 10 millibar level down to 600 millibars, with a temperature minimum, in the tropopause, of 51 degrees Kelvin.

As the radio beam brushed the outer fringes of the Uranian atmosphere, the investigators saw signs of rapid intensity fluctuations indicative of ionospheric layers above the main atmosphere, a finding consistent with the ultraviolet emissions and high temperatures measured by the ultraviolet experiment. As the beam probed deeper and deeper into the Uranian atmosphere, it cut through the stratosphere and the temperature dropped. The temperature reached a minimum of 51 degrees Kelvin; this figure was, however, set by the infrared experiment.





The bright pinkish streak in this computer-processed, false-color Voyager image is a high-level cloud in the Uranian atmosphere. Several other cloud features, as well as darkish belts and light-toned zones, are also discernible in this nearly pole-on image, especially if you view the page from several feet away. JPL/NASA image P-29468.

At the tropopause the temperature curve reversed, rising to 68 degrees Kelvin at 600 millibars pressure. As it cut through the troposphere, the radio beam encountered convection and wave motions that caused the signal to scintillate, or twinkle. Deeper still, the radio beam entered the main Uranian cloud deck, passed through clouds of methane ice, and then revealed the cloud bottom at some 1.6 bars pressure and 82 degrees Kelvin temperature. At its deepest, the radio beam was reduced to about $1/1{,}000$ of its original intensity and penetrated the atmosphere to the 2.5-bar pressure level.

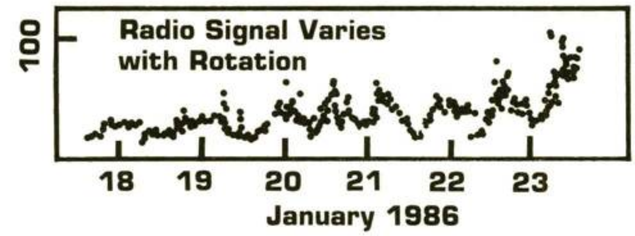
The atmosphere of Uranus, as measured by several of Voyager's experiments, consists primarily of hydrogen, plus 12% helium by volume. This figure is, however, somewhat uncertain. The radio occultation experiment measured the refractivity of the atmosphere. This, however, depends on the composition and density of the atmosphere, which is not well known. Nonetheless, combining the refractivity with data from the infrared experiment allows the scientists to determine the temperature and to establish limits on the density, and to rule out large concentrations of heavy hydrocarbon compounds that would raise the density of the gases. Large

"The magnetosphere of Uranus is far more weird and wonderful than we would have expected."

— Fran Bagenel

concentrations of hydrocarbons would decrease the amount of helium required to match the radio data. The Voyager team concluded that a 12% mix of helium, plus or minus 4%, gave the best fit.

The infrared experiment independently produced a similar helium concentration. By fitting spectra obtained by the IRIS instrument with computer-generated synthetic spectra containing different mixes of helium, the scientists obtained the best fit with approximately 10% helium. This is similar to the helium abundance of Jupiter, but considerably higher than that in Saturn's atmosphere. At Saturn, however, helium has been segregated in the planet's core. The solar helium abundance is roughly 14%.



In addition to its primary constituents, hydrogen and helium, Uranus' atmosphere contains a few parts per million of methane. Characteristic absorption bands of acetylene and heavier hydrocarbon molecules were found in the infrared spectra of the planet. The heavy molecules are formed by the action of ultraviolet light on the methane and acetylene in the planet's atmosphere — just as terrestrial smog is formed. Heavy molecules are, however, quite rare. Only one molecule in 10^8 is a molecule of a heavy hydrocarbon. By examining the reflectance of the planet at the ultraviolet wavelengths absorbed by these hydrocarbons, the photopolarimeter determined that most of these molecules lie near the 130 millibar pressure level in the atmosphere.

The Ionosphere

Above the 1 microbar pressure level, the gases in the Uranian atmosphere no longer mix. This level, where the atmosphere ceases to be homogeneous, is called the homopause. Above the homopause, the atmosphere consists almost entirely of hydrogen, both molecular (H_2) and atomic (H). Over the sunlit south pole of Uranus, the ionosphere reaches a temperature of 750 degrees Kelvin; over the dark north pole, it reaches 1,000 degrees Kelvin. What heats the gas to such a high temperature is not evident. The source of energy is not sunlight because the dark pole is hotter, so it probably derives its energy from the magnetosphere. Heating this gas does not require a large energy *input because* so tenuous a gas will not cool itself efficiently.

The region above the homopause emits a considerable amount of ultraviolet Lyman-α. Although they saw the "electroglow" at Jupiter and Saturn, Voyager scientists had not recognized this radiation as a new process until they saw it at Uranus, where it was relatively more intense. Voyager was not the first to observe the electroglow: the International Ultraviolet Explorer satellite observed it from Earth orbit. The Voyager scientists expected Uranus to have intense daytime aurora, but Voyager showed that the distribution of ultraviolet light was not that of aurora or dayglow. Electroglow may be powered by low-energy electrons from the magnetosphere, but how this works is not yet understood.

In addition to the electroglow, Voyager also found aurora at Uranus. On the planet's dark north pole, the ultraviolet spectrometer detected characteristic auroral radiation and verified that it rotated with the planet. Aurora is generated when high-energy electrons collide with atoms and molecules in the upper atmosphere.

The Rotation of Uranus

Uranus rotates on its axis in approximately 17 hours. A reliable measurement of this fundamental datum had eluded ground-based observers for over 200 years, and it even eluded Voyager 2's sensors until a few days before closest encounter. Due to the lack of cloud detail — which may not, in any case, reflect the rotation of the bulk of the planet — and the unusual configuration of its magnetic field, the first real indication of the planet's rotation came from radio noise that regularly varied in intensity.

As the spacecraft approached the planet, the noise became more intense, but interference from the spacecraft itself made deriving an accurate period of rotation from the radio signals difficult. On the basis of a fifteen-day run of data, the rotational period was 16.8 hours with an uncertainty of 0.3 hours.

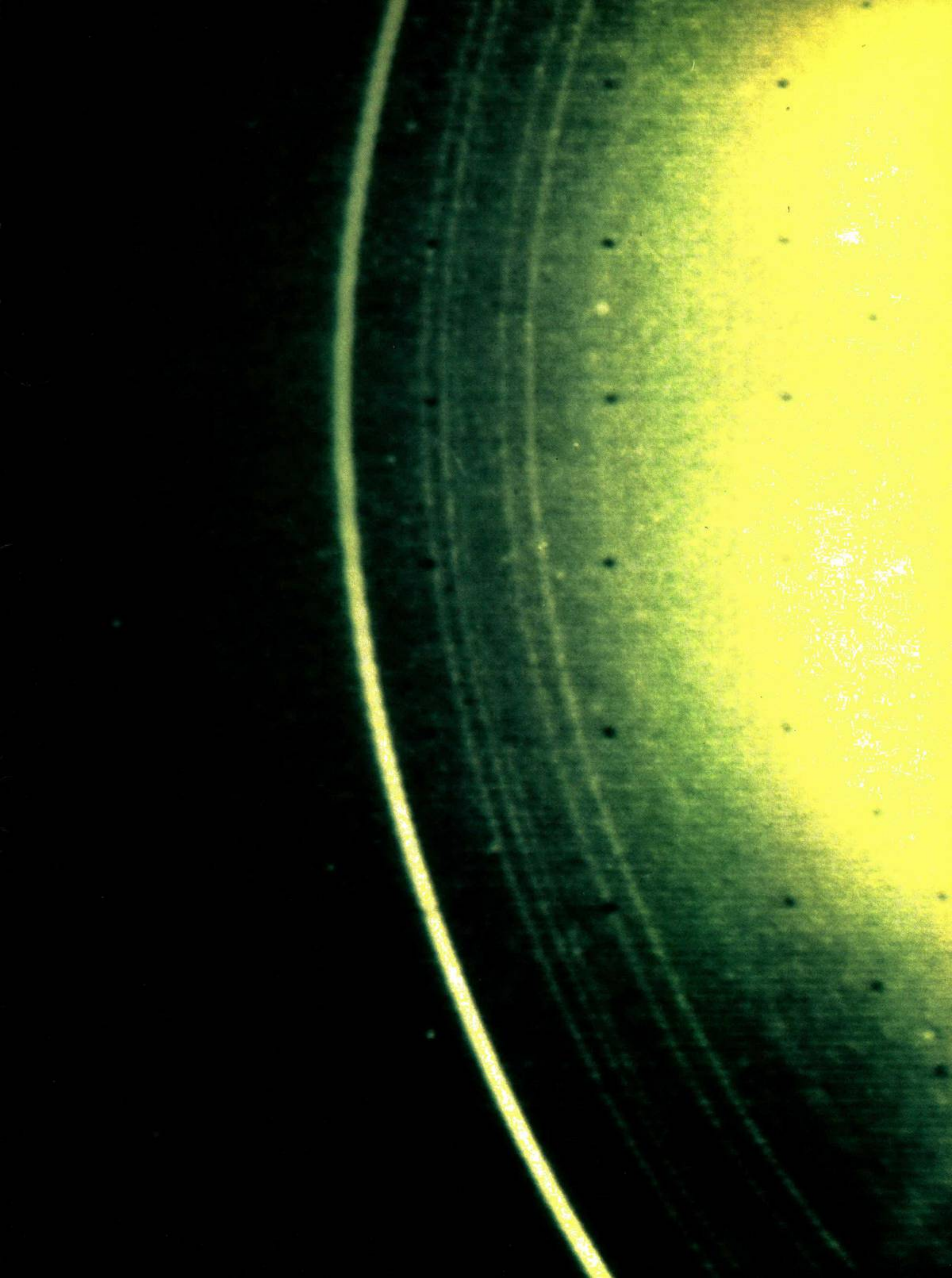
After Voyager passed Uranus the strength of the radio signals increased roughly 100 times, strong enough for Voyager to monitor for several weeks after passing the planet. Modulations in the signal strength will eventually permit determining the rotational period of the planet with an uncertainty of roughly one minute.

The Uranian Magnetic Field and Interior

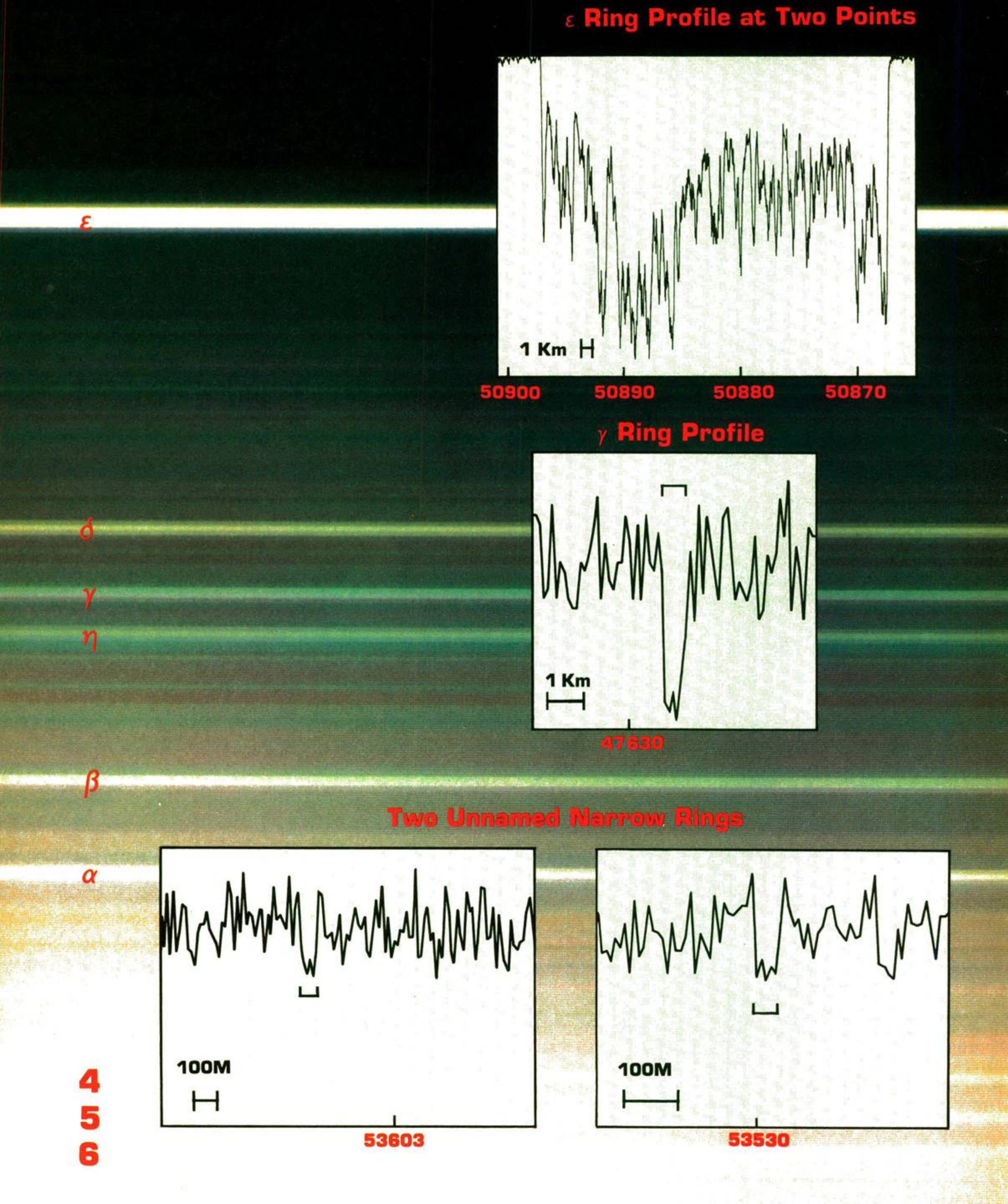
Before the Voyager encounter, some scientists had predicted that Uranus might have little or no magnetic field. But Uranus does have a magnetic field, and it is tipped 55° to the rotational axis of the planet. The total energy bound up in the Uranian magnetic field is about $\frac{1}{10}$ that of Saturn's magnetic field, $\frac{1}{400}$ that of Jupiter's, and 50 times that of Earth's magnetic field. The presence of a strong and unusual magnetic field implies that Uranus contains some sort of circulating conductive material — what scientists call a "dynamo."

Since it originates in the deep interior, a planet's magnetic field gives clues to the internal structure of the

Nine narrow rings encircle Uranus. (The greatly overexposed image of the great green giant planet lies outside the frame.) From left to right, the rings are named the epsilon, delta, gamma, eta, beta, alpha rings. The 4, 5, and 6 rings are very faint in this image. Voyager's cameras also found a tenth ring between the epsilon and delta rings, as well as a tenuous skein of dust in the ring plane. The *photopolarimeter instrument* detected traces of hundreds of very narrow, possibly partial rings where they blocked the light of a star during a stellar occultation experiment. JPL/NASA image.



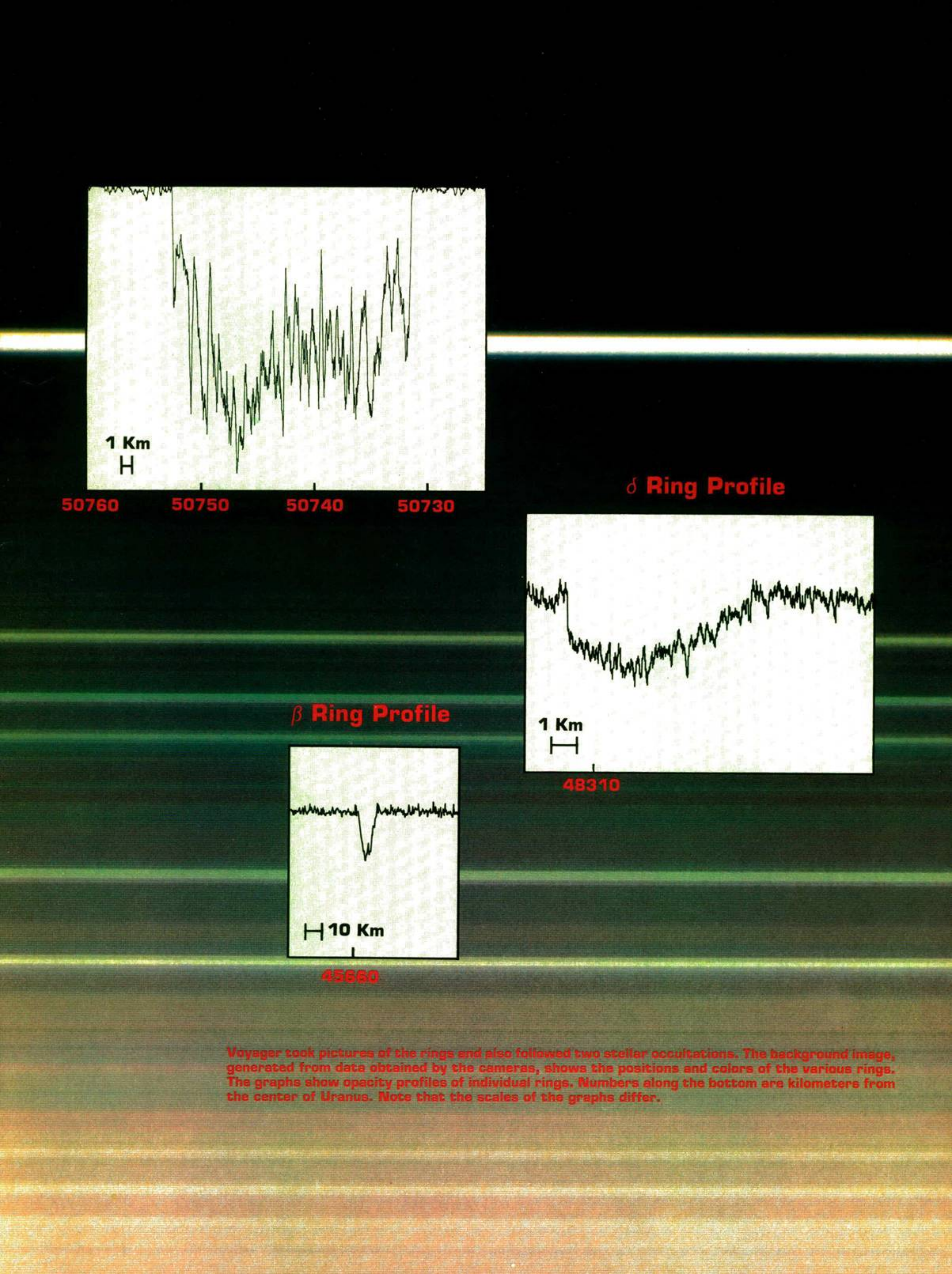
The Uranian Rings



ε Ring Profile at Two Points

γ Ring Profile

Two Unnamed Narrow Rings



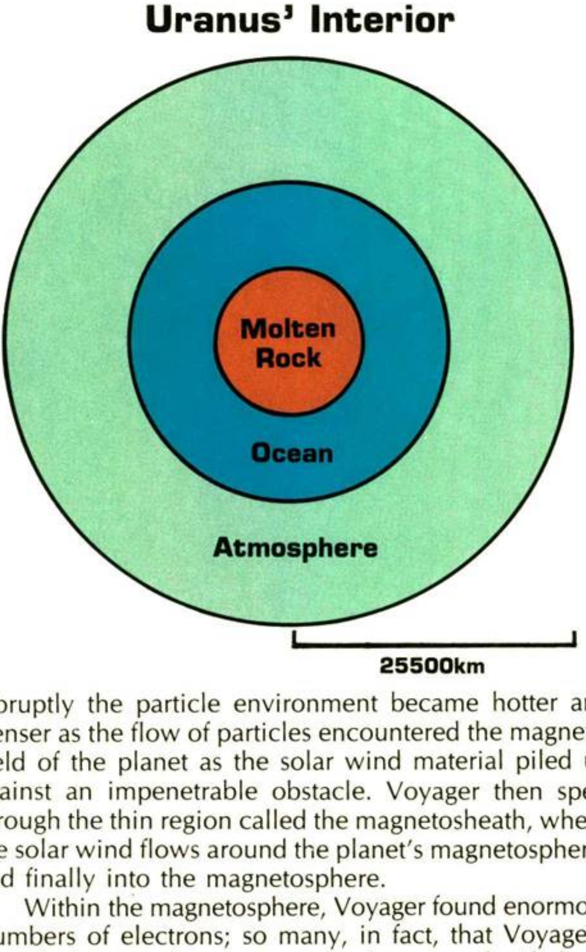
Voyager took pictures of the rings and also followed two stellar occultations. The background image, generated from data obtained by the cameras, shows the positions and colors of the various rings. The graphs show opacity profiles of individual rings. Numbers along the bottom are kilometers from the center of Uranus. Note that the scales of the graphs differ.

> **"The outer planet missions have really changed our way of thinking about how solar system bodies develop."**
>
> — Hal Masursky

planet. Uranus' overall density is considerably greater than Saturn's, for example, suggesting the planet has a molten silicate ("rock") core about the size of Earth (13,000 kilometers in diameter) enveloped in an 8,000-kilometer deep "ocean" composed primarily of water, and wrapped in an 11,000-kilometer-thick hydrogen-helium atmosphere. Currents in the water shell, driven by the heat of the molten-rock core, could act as a dynamo for the magnetic field.

The Magnetosphere

As Voyager approached Uranus, the particle environment around it changed. Upstream of the planet in the solar wind, Voyager was bathed in a sea of protons and helium nuclei flowing smoothly outward from the Sun. Abruptly the particle environment became hotter and denser as the flow of particles encountered the magnetic field of the planet as the solar wind material piled up against an impenetrable obstacle. Voyager then sped through the thin region called the magnetosheath, where the solar wind flows around the planet's magnetosphere, and finally into the magnetosphere.



Within the magnetosphere, Voyager found enormous numbers of electrons; so many, in fact, that Voyager's particle detectors became completely saturated with them. In addition to their unexpected numbers, the spectrum of the electron energies is also quite unusual. Normally for every electron at a given energy, there might be, for example, 100 at $\frac{1}{10}$ that energy. In the Uranian system, for every electron at a given energy, there are 10^{12} electrons at $\frac{1}{10}$ that energy. The lack of high-energy electrons is simply not understood since there are numerous ways for electrons to gain energy in a plasma.

Within the magnetosphere, the positively charged particles are mostly protons plus a small number of carbon and oxygen ions. Voyager found two distinct "populations" of ions: one is a dense, "warm" population at a temperature of a hundred thousand degrees Kelvin and a density of 1 ion per cubic centimeter. These ions are trapped by the magnetic field and rotating with the planet. The other is a 10 times less dense plasma at a temperature of ten million degrees Kelvin. The "hot" ions tend to drift toward the planet, but it appears that Uranus' innermost moderately-large satellite Miranda absorbs nearly all of them.

Where could these hot ions come from? The solar wind, one possible source, is deflected around Uranus. Instead, the ions must come from either the upper atmosphere of Uranus or from the hydrogen in the icy surfaces of the planet's outer satellites.

Miranda and the Uranian rings seem to play an important role in the magnetosphere, for not only are their surfaces a source of particles, but they also act as sinks for energetic ions buzzing up and down the magnetic field lines. Although they have normal orbits the satellites trace complex paths through the rapidly rotating and highly inclined magnetic field, soaking up the energetic particles that impact on them and leaving some magnetospheric zones depleted of ions. Inside Miranda's orbit, the small satellites and the rings preferentially collide with positive ions. Miranda, the smallest of the major Uranian moons, and the ring particles may selectively absorb heavy positive ions, which spiral tightly about the magnetic field lines. They do not absorb the lighter electrons.

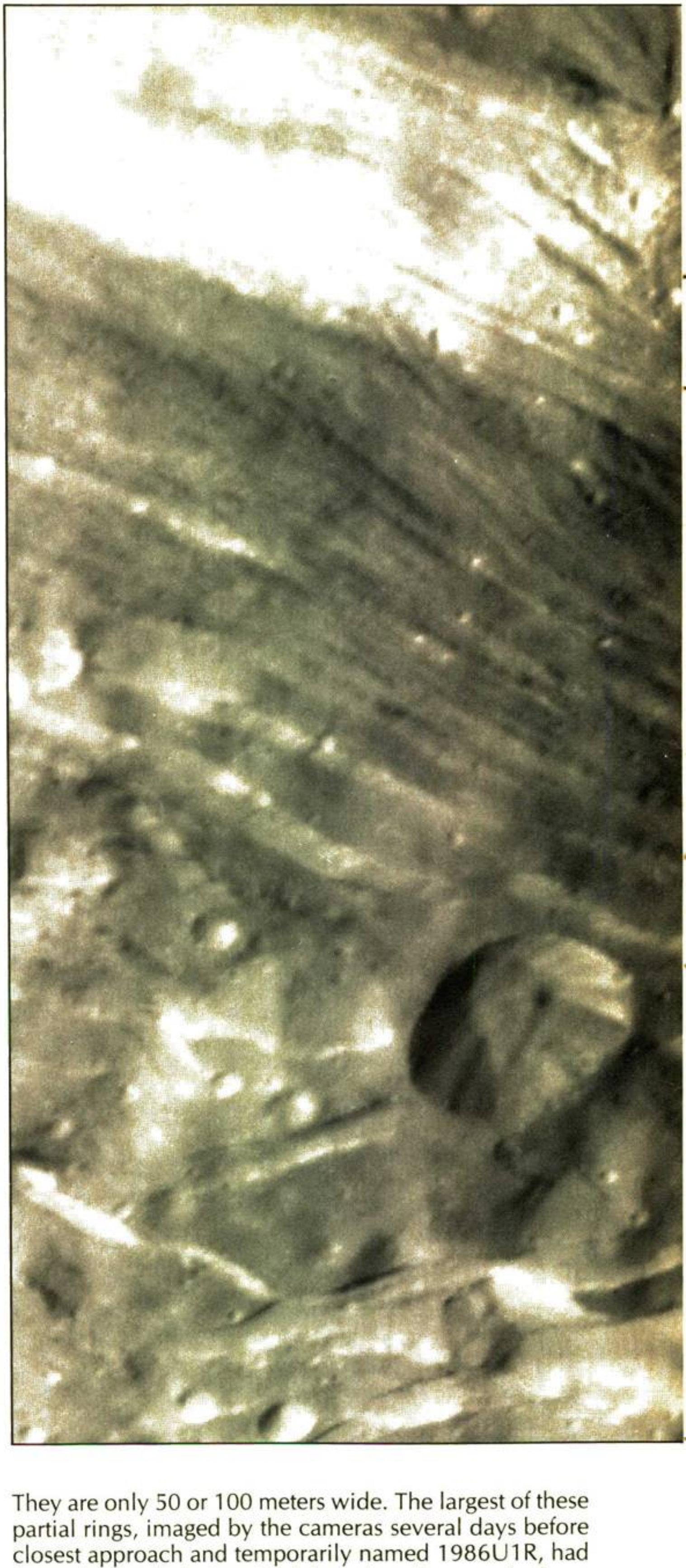
In some ways the Uranian magnetosphere is similar to the Jovian and Saturnian magnetospheres. Uranus has rings and satellites that add and remove plasma. But the large tilt of the magnetic field makes the Uranian magnetosphere's behavior quite different from Jupiter's and Saturn's — and very exciting — to magnetospheric physicists.

The Uranian Rings

The rings of Uranus have very little mass. The entire ring system, in fact, contains only about as much material as the Cassini Division of Saturn's ring system. So tenuous are they that the rings of Uranus escaped notice until only nine years ago. While astronomers aboard NASA's Kuiper Airborne Observatory were trying to measure the depth of the planet's atmosphere by observing how the planet blocked the light of a star, several rings momentarily

By combining all of the high-resolution images of Miranda into a single picture, the Voyager 2 imaging team produced this striking image of Uranus' strangest satellite. The 480-kilometer-diameter body shows both compressional (pushed together) ridge features and extensional (pulled-apart) fault features. Prominent are three large circular features that the imaging team has dubbed "circi maximi" ("circus maximus" in the singular). One is at the lower left, one is at the upper right, and the third (trapezoidal in shape) is near the center of the disk. Circi maximi tend to be darker than the rest of the surface and show grooves parallel to their edges. JPL/NASA photo P-29541.

Two distinct land forms are visible in this image of Miranda: a higher, older, cratered, rugged terrain and a lower, less-cratered, striated terrain. Both terrains are cut by numerous scarps and faults. A spectacular cliff possibly 20 kilometers high lies where the two land forms meet at the terminator. Part of the "chevron," one of Miranda's enigmatic circus maximus features, lies in the upper left corner of this frame. The largest crater in this image (lower left) is about 25 kilometers across. JPL/NASA photo P-29512.



blocked the starlight. By repeated and careful measurements, astronomers traced the paths of nine narrow rings.

During its brief encounter with Uranus, Voyager investigated the nature of the Uranian ring system. To do this, the photopolarimeter monitored occultations of two stars by the rings, obtaining profiles of the major rings plus evidence suggesting that hundreds of narrow, all-but-invisible ringlets also orbit the planet. Voyager's cameras found a tenth ring and detected the gossamer sheen of fine dust in the ring plane.

The "Big Ten" Rings

The stellar occultations provided profiles of the rings 100 to 1,000 times finer than the best images produced by the cameras and revealed structure down to 10 meters across. In addition to optical measurements, the radio occultation experiment (which probed the atmosphere) also probed the ring system at two different wavelengths. Cursory early analysis of the data show that the rings have distinctly different characters.

The epsilon ring, the outermost and broadest of the Uranian rings — is some 43 kilometers across. It is flanked by shepherd satellites temporarily named 1986U7 and 1986U8. The ring is eccentric and appears twinned in the sharpest images taken by the cameras. The stellar occultation profiles reveal the doubling seen by the cameras plus fine-scale "chaotic" structure. The two chords sampled at different places in the ring have different widths and the structure within the ring varies. The optical data show that on one chord, the outer edge of the ring is very sharp, going from fully-packed ring to empty space in less than 50 meters. The inner edge is also sharp, some 500 meters wide. The radio experiment showed virtually identical epsilon ring profiles at S-band and X-band frequencies (3.6 and 13 centimeter wavelengths, respectively). Preliminary analysis of these data suggests that most of the particles in the epsilon ring are larger than one meter in diameter.

The next ring inward is the delta ring, with three major components observed at one occultation but only one observed at the second. The alpha ring shows four components, three broad ones and one bright, narrow component. The beta ring has two broad components and a narrow one.

The stellar occultations showed the gamma ring to be very narrow — only 600 meters across — with edges 100 meters wide. Such sharp edges also imply the ring is very thin. This ring's extreme narrowness is confirmed by a set of images showing the rings silhouetted against the illuminated ball of the planet near the time of closest approach. Although the gamma ring appeared clearly in front-lit images, it was invisible in the silhouettes. In contrast, the eta ring is broad and diffuse even in images taken with Voyager's cameras.

These observations also turned up ten very narrow ring arcs, or sections of ring, in approximately 5% of the data. This implies that when the entire ring system has been searched, several hundred such rings will be found. They are only 50 or 100 meters wide. The largest of these partial rings, imaged by the cameras several days before closest approach and temporarily named 1986U1R, had been detected during Earth-based stellar occultations. Because the ring arc was not seen at both sides of the planet, this "blip" in the data had been discounted.

Ring Dust

Saturn's rings are so filled with fine dust — particles a micrometer in diameter — that some regions appear brighter from behind than they do from the sunward side

due to the forward-scattering properties of fine particles. Uranus' rings, in contrast, are almost devoid of fine dust and much fainter from behind than from the front.

One long-exposure image, taken from the shadow of the planet itself, showed the rings illuminated in forward-scattered light. The amount of dust present is, however, very slight. Based on the brightness of the light and the scattering geometry, there is $\frac{1}{10}$ as much dust in Uranus' rings as in Saturn's most tenuous ring, the D ring. If it were gathered into a single body, the dust would make a ball no more than 100 meters in diameter.

Since ring dust probably comes from collisions between ring particles, Uranus' rings almost certainly generate dust. What then happens to it? Some Voyager scientists believe that electromagnetic forces sweep the dust out of the rings. Because the magnetic field is so highly inclined to the rotational axis of the planet (hence, to the ring plane), if a dust particle becomes charged by collisions with energetic ions then the magnetic field will tend to remove it from the rings. In addition, since the

"It doesn't take a scientist to recognize that these planets are different."
— Ed Stone

ring is embedded in the extended hydrogen atmosphere of the planet, gas drag also helps remove the particles. In either case, dust doesn't last long in the Uranian system.

Voyager also found a tenuous cloud of dust when it crossed the ring plane. Using its radio antennas to detect the tiny explosions of impacting particles, Voyager recorded 30 hits per second at a distance of 4.5 Uranus radii from the planet. (At Saturn, Voyager recorded 600 hits per second at ring plane crossing.) So far outside the Uranian rings, however, this much dust comes as a surprise.

The Satellites of Uranus

Voyager mapped the sunlit surfaces of all five major moons — Miranda, Ariel, Umbriel, Titania, and Oberon — and imaged the new-found satellite 1985U1. Miranda, the smallest of the major five, is 480 kilometers in diameter. 1985U1 is one-third Miranda's diameter. Ariel and Umbriel are both roughly 1,200 kilometers in diameter, and Titania and Oberon are roughly 1,600 kilometers in diameter.

Instead of a system of crater-pocked hard-frozen iceballs, Voyager found that all the major Uranian moons, with the possible exception of Umbriel, have been tectonically active at some time in their past. Both Miranda and Ariel are split by deep cracks and other signs of internal activity, and Miranda alone exhibits strange dark, grooved regions called "circi maximi" and spectacular cliffs and faults. Titania, though less active than its smaller neighbors, is cut by deep valleys.

The optical navigation team found that these satellites have densities around 1.6 grams per cubic centimeter; in other words, they are composed of a 50-50 mix of water ice and rock. What, then, explains their darkness? The answer is dark carbonaceous chrondrite material, material that dates back to the formation of the solar system and is composed of magnetite, organic compounds, and carbon.

Geology of the Big Satellites

As black as coal, tiny 1985U1 was squeezed into the imaging schedule at the very last moment by retargeting a single exposure originally intended for Miranda. A single imaging frame taken from a range of half a million kilometers shows that this small object is round, and one prominent crater shows on the terminator. The disk has a mottled appearance suggesting that the body is heavily cratered, but the resolution of the image is not sufficient to show craters clearly.

Tiny Miranda, which the Voyager scientists anticipated would be the quintessential crater-pocked iceball, turns out to be one of the more geologically active bodies in the solar system. Spotted with large circular dark regions nicknamed "circi maximi," ancient cratered terrain that seems to have been crumpled on itself, and valleys bounded by towering cliffs, Miranda displays all the oddest terrains from all the odd worlds in the solar system.

There are regions of old, softly-contoured, cratered terrain like those on Saturn's satellite Mimas. However, sharp-edged faults cut through some of these areas, suggesting internal activity after the old cratered terrain had been softened by subsequent bombardment. In other areas, this ancient terrain appears crumpled in compression, like parts of Mercury's surface.

However, the unique feature of Miranda's surface are the "great racetracks," or "circi maximi." Resembling the "regio" of Ganymede's surface, the terrain in them may be groovy like that on Ganymede or chaotic ridges like that on Enceladus. Three circi maximi are visible on the Voyager images of Miranda. They tend to be dark inside and consist of grooves, ridges, or cliffs parallel to the outer rim. Of the three we see, two are circular. The third, the one which contains the "chevron" feature, is trapezoidal in shape. All three appear to result from some sort of process that builds outward from the center by faulting. The three features visible on the Voyager images may be different stages in the growth of the same basic landform.

Ariel's surface bespeaks a rich and complex history, though it pales beside the positively baroque surface of Miranda. Besides having the brightest surface in the Uranian system, Ariel has a large range of variation in reflectivity. The brightest areas are 45% reflective, while the darkest are approximately 25% reflective.

Ariel's surface displays ray craters, intersecting valleys and scarps, faults, and what appear to be flow features. There are places where faults don't cross valley floors because the valleys, presumably, have been subsequently filled. In addition, underlying the more recent tectonic features is a soft-edged crater population that presumably dates back to Ariel's formation.

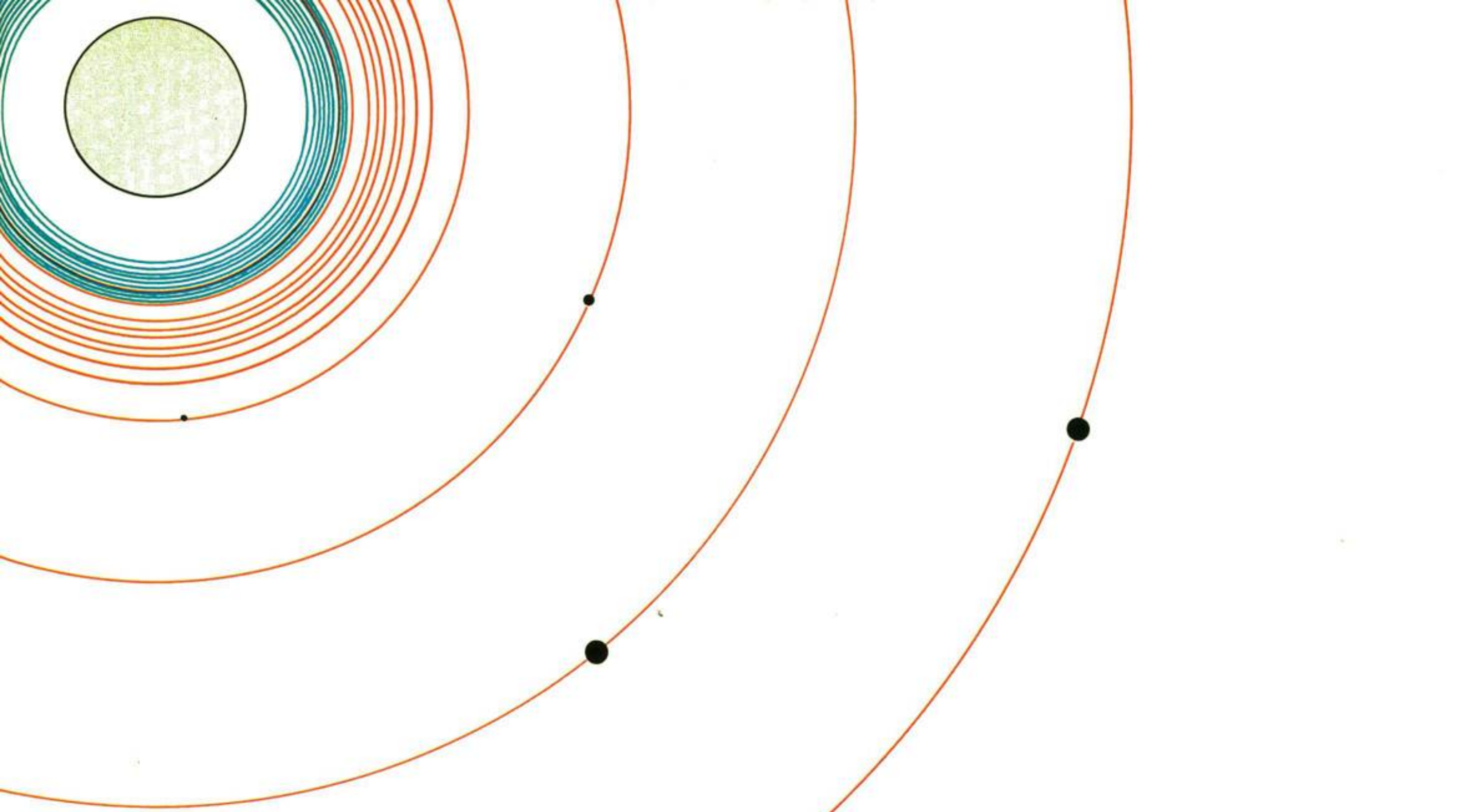
Ariel's surface strongly suggests that it has undergone a variety of geological episodes in its history and that non-tectonic processes — perhaps water or ice flows from the interior — have played a role in forming the floors of its valleys.

Dull gray Umbriel is covered with muted, overlapping craters and impact basins up to 200 kilometers in diameter. As the darkest of the large Uranian satellites, Umbriel averages 15% reflectivity with only small variations from this value. (The small Uranian satellites are thought to be 5% reflective, or as black as coal.) While such reflectivity is entirely reasonable for a rocky body, it is low for an object with an icy surface.

The most unusual feature seen by Voyager is a "white" ring about 150 kilometers in diameter near the satellite's limb. The ring has a reflectivity of 25% — dark gray — but is the brightest feature on Umbriel. It appears to be the floor of a crater, but the ring lies near the limb and cannot be seen clearly.

Neutral gray Titania sports bright ray craters, complex graben-like trenches, subtle tectonic depressions, and large impact basins. The trenches, found near the terminator, are part of a large system of faults that spans half the body's diameter. The trenches appear to be the result of tensional faulting.

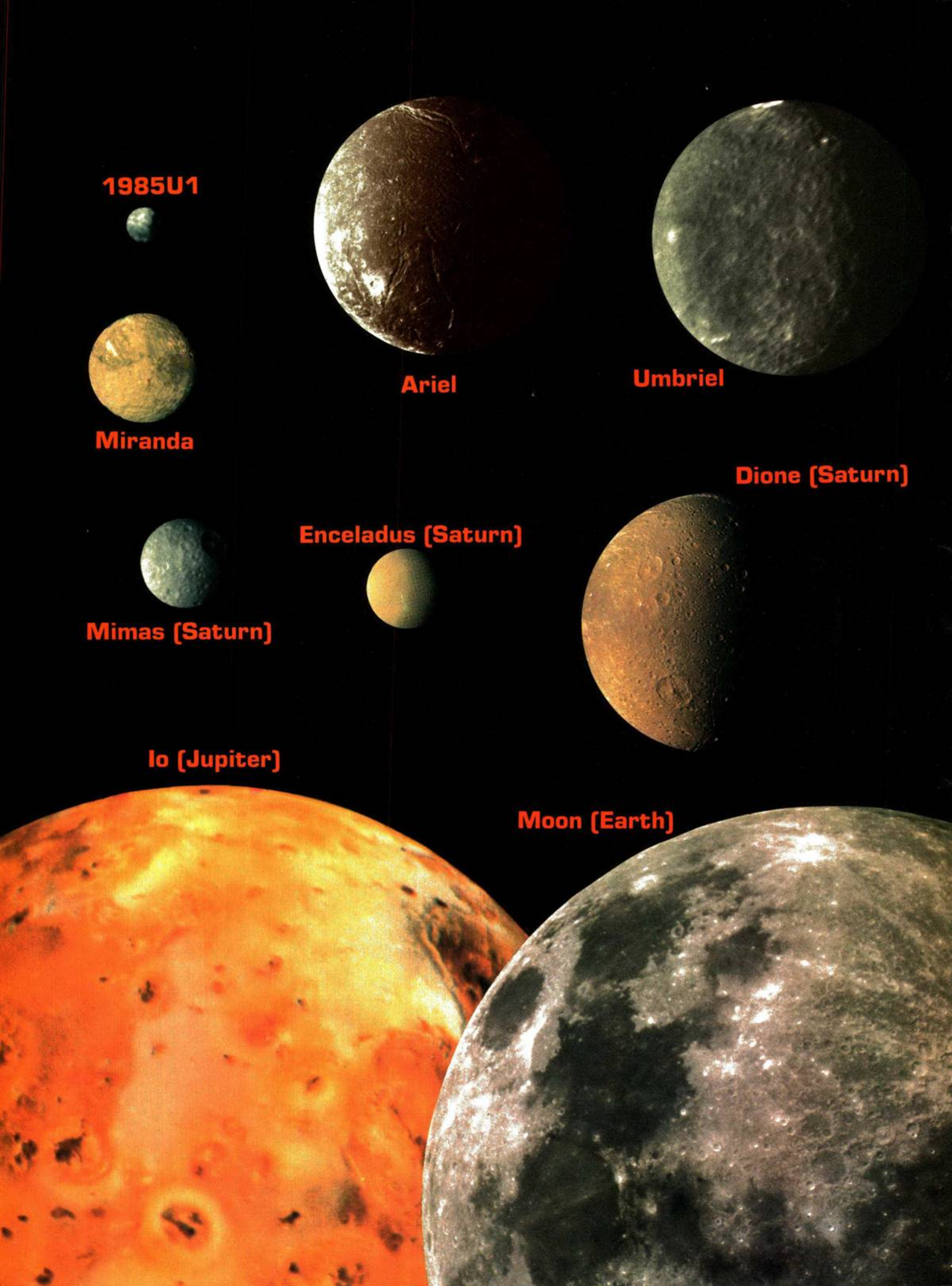
A large basin seen near the terminator at the time of the Voyager encounter is evidence of heavy bombardment

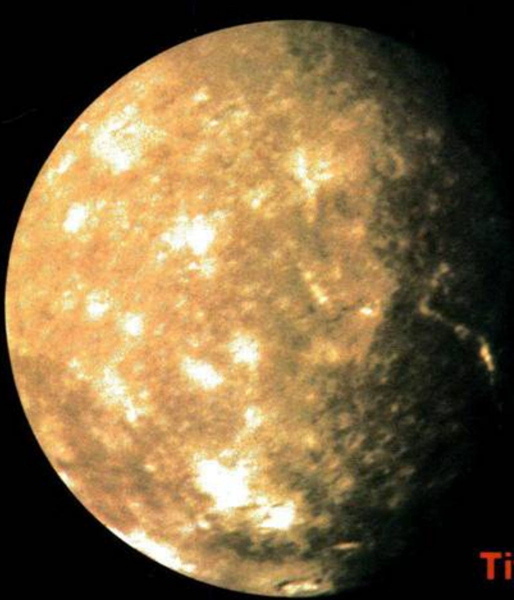


The Uranian Satellites

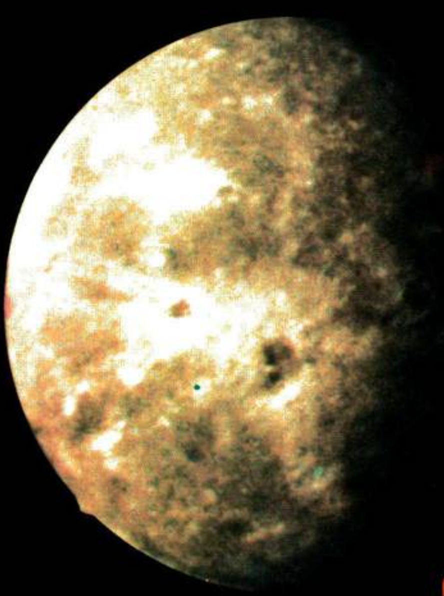
Name	Diameter†	Orbit	Period	Description
1986U7	15*	49,300	7h 55m	Epsilon ring shepherd, d. 1/20/86
1986U8	20*	53,300	8h 55m	Epsilon ring shepherd, d. 1/20/86
1986U9	50*	59,100	10h 23m	Discovered 1/24/86
1986U3	70*	61,750	11h 06m	Discovered 1/9/86
1986U6	50*	62,700	11h 24m	Discovered 1/13/86
1986U2	70*	64,350	11h 50m	Discovered 1/3/86
1986U1	90*	66,090	12h 19m	Discovered 1/3/86
1986U4	50*	69,920	13h 24m	Discovered 1/13/86
1986U5	50*	75,100	14h 56m	Discovered 1/13/86
1985U1	160x170	85,892	18h 17m	Cratered, dark surface, d. 12/30/85
Miranda	480	129,390	1d 9h 55m	Tectonically active, complex surface
Ariel	1,170	191,020	2d 12h 29m	Resurfaced, many faults and grabens
Umbriel	1,190	266,030	4d 03h 28m	Cratered, dark surface
Titania	1,590	435,910	8d 16h 56m	Cratered, large faults present
Oberon	1,550	583,520	13d 11h 07m	Cratered, some crater floor activity

†Diameter derived from assuming dark surface, otherwise measured from Voyager images.
*Measurement errors of ±25 km.


1985U1
Ariel
Umbriel
Miranda
Dione (Saturn)
Enceladus (Saturn)
Mimas (Saturn)
Io (Jupiter)
Moon (Earth)



Titania



Oberon

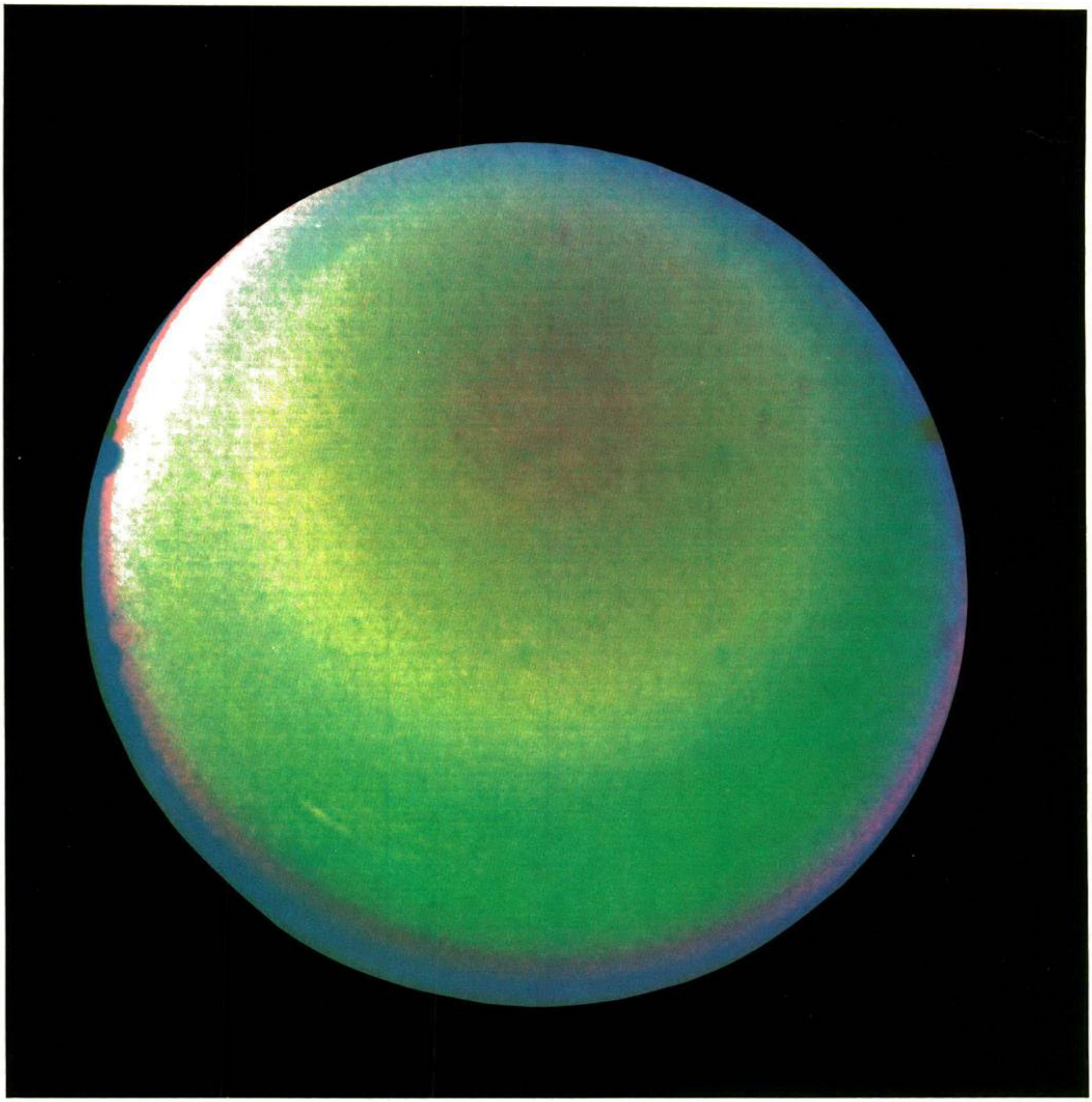
The Uranian Moons as Planetary Satellites

The "Big Four" Uranian satellites — Ariel, Umbriel, Titania, and Oberon — are similar in size to Saturn's "small" moons — Dione, Tethys, Rhea, and Iapetus. Miranda is similar in size to Mimas, Phoebe, or Hyperion. 1985U1 resembles Saturn's A-ring shepherds or the co-orbital satellites in size. (For background on the Saturnian and Jovian satellites, see "Four New Worlds," September 1980 ASTRONOMY, and "The Saturnian Satellites," December 1981.)

JPL/NASA photos;

Earth's Moon by Jacques Guertin.

Ganymede (Jupiter)



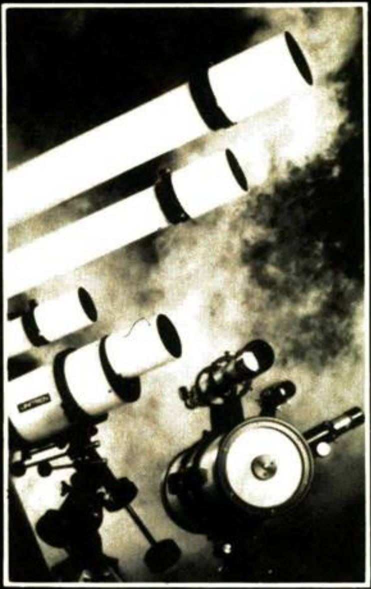
This pole-on image of Uranus displays the major features in the planet's atmosphere in artificial color. The polar region, relative to the rest of the planet, is slightly reddish. Surrounding the pole is a broad ring of haze, yellowish in this image, lofted into the upper atmosphere from below. The elongated bright cloud plume (at latitude 33°) is a site of strong convection from the lower atmosphere that is a feature of the main methane-ice cloud mass. The limb of the planet, here visible as a white or purplish area, appears bright because of high-level haze in the atmosphere. Color composite of JPL/NASA images.

in the past. Its low relief suggests that the materials forming Titania could not support its original topography. Overall, Titania lacks large craters; those it has are small and are relatively uniform in size. This moon may have been recratered at a stage late in its formation by low-velocity debris thrown off by a few large impacts.

The photopolarimeter observed the surface microstructure of Titania by measuring the strength of the "opposition effect." (Rough surfaces, like highway signs, brighten when they are lit head on. This brightening is called the "opposition effect.") The observations show that Titania's surface is very rough and probably consists of highly pulverized rock produced by micrometeorite gardening or heavy bombardment by very energetic ions. It rules out recent remelting or volcano-like flows on the surface. Titania was studied because the geometry of the Voyager approach was best for this body.

Oberon, the most distant of Uranus' satellites, is rather dark, with a reflectivity of about 20%, and bears several patches of much darker material. On the limb of this satellite, a lone mountain rises six kilometers from the otherwise circular profile. One large scarp is visible and several large craters display dark pools on their floors, suggesting that dark material from the interior must have flowed out some time after the formation of the crater.

— Richard Berry



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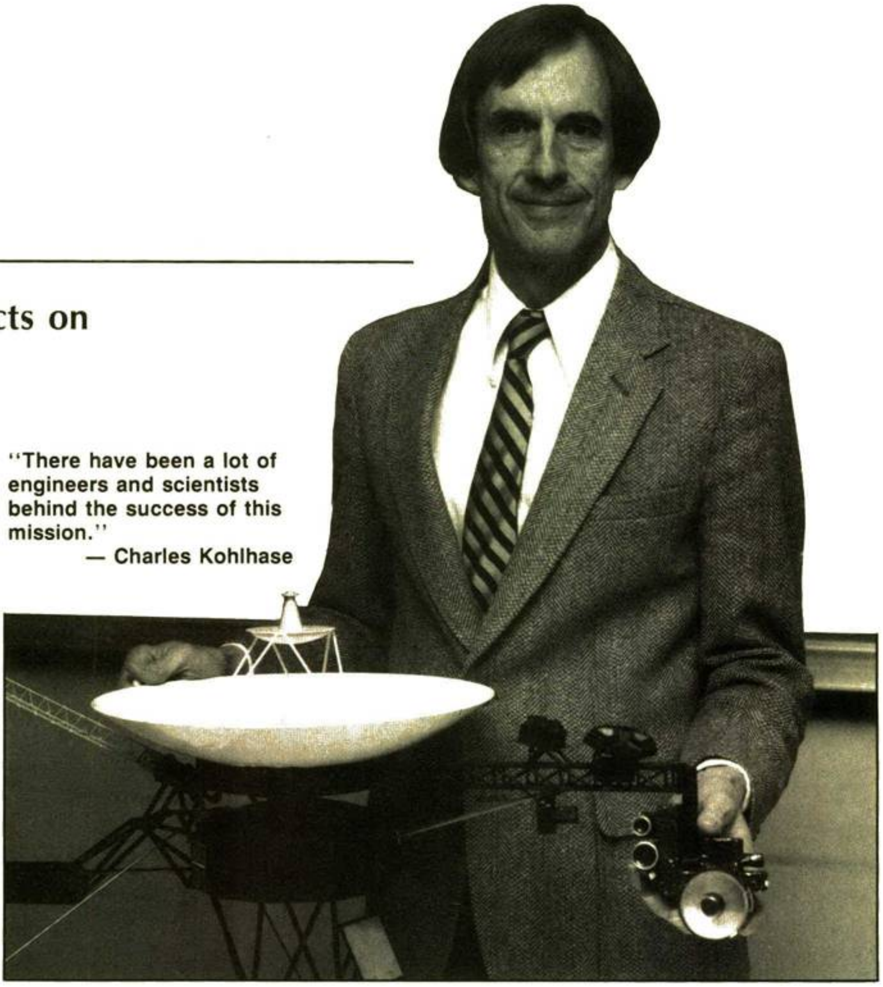
The Voyager 2 Team Reflects on A "Wonderful Mission"



"There have been a lot of engineers and scientists behind the success of this mission."
— Charles Kohlhase

"Voyager has been an amazingly successful and wonderful mission," says Charley Kohlhase, manager of the Voyager Mission Planning Office. The mission began in the summer of 1977 when Voyager 1 and Voyager 2 were launched. The spacecraft are making a one-way journey through the solar system, transmitting information back to Earth about the outer planets and their surroundings. Voyager 1 flew past Jupiter and Saturn. Voyager 2 has already encountered Jupiter, Saturn, and Uranus and is now on its way to Neptune.

The scientists and engineers who comprise the Voyager team have been through a lot together. During the flight, both spacecraft experienced problems. Voyager 1's scan platform stuck for a short period. Then Voyager 2 became tone deaf (its primary receiver failed and the backup lost its full ability to lock on to the sending frequency). Voyager 1 became partially blind (its photopolarimeter failed). The team acted in unison to deal with these problems and, as a result, the Voyagers continued on to spectacular successes.

What has this mission meant to the people who have guided Voyager's progress? "The Voyager mission has been inspirational in keeping me alive as a person," says Charley Kohlhase. He adds that the challenges of Voyager have continued throughout its almost nine years of flight. When it was launched, Charley had to sweat out the possibility that Voyager 1 might not achieve its Jupiter trajectory due to off-nominal mixing of fuel and oxidizer in its Titan III/Centaur booster. At Uranus and now Neptune (scheduled for encounter on August 24/25, 1989), one of many challenges involves targeting the spacecraft based on imperfect knowledge of the planet, moon, and ring locations. Voyager 2's approach to Neptune will take it near the planet's rings and within 800 miles of its cloud tops for an encounter with Mercury-sized Triton.

Charley is also involved in public relations. This includes giving talks all over the country, appearing on television, and once being sandwiched in between William Shatner and DeForrest Kelly (Captain Kirk and Bones) at a Star Trek convention. Charley would "have the media realize that there are lots of engineers and scientists who have been behind the success of the mission. Sometimes they just don't get enough credit.

"Voyager has become a national asset," he adds. "It has the only chance in all history to closely view Uranus and Neptune. In fact, there will not be another opportunity for the 'Grand Tour' (an infrequent and opportune alignment of the major planets of our solar system) for another 168 years." Voyager is a "good effort. . . . We're not polluting the environment, we're not building more nuclear weapons."

Charley's personal responsibility during the Uranus flyby was planning the major events of Voyager's encounter. Imaging Miranda was a major achievement. Precisely locating Voyager and Miranda led to perfect pictures of one of the most fascinating bodies encountered by Voyager.

For Steve Synnott, leader of the Voyager *Optical* Navigation Team and an associate member of the Imaging Science Team, working the Voyager mission has made him feel that it's

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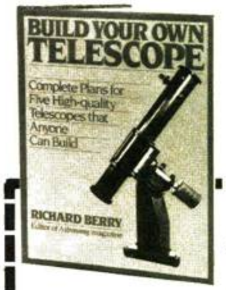

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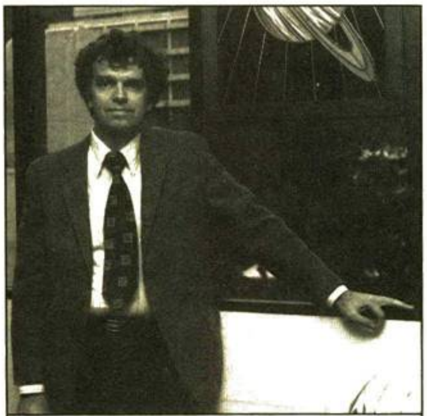
"The one day around closest approach just flashed by. You wanted to hold time still."
— Linda Horn

"great to go to work tomorrow." Steve has the distinction of discovering nine new moons (seven at Uranus alone), and he has been involved in the discovery of four others.

Steve says his work is "not a spectacular individual achievement, but a nice piece of work . . . and there are a lot of people doing nice pieces of work." Steve is responsible for the software used to search for satellites, a task that often requires examining the individual pixels of an image.

"When Voyager ends it will be like parting with an old friend," says Linda Horn, an experiment representative for Voyager's Infrared Imaging Spectrometer (IRIS). "Uranus took two years to plan and the day of closest approach just flashed by. You just wanted to hold time still. There are pictures you want to see and data you want to get back. You just bring in your sleeping bag and stay here. The best part of the encounter is that feeling of family."



***"This* was the best encounter yet. Things could not have gone better."**
— Doug Griffith

Sue Linick, another mission employee, and Linda Horn planned the births of their children around the Voyager encounters. They both have two children born between Voyager's Saturn and Uranus encounters. Linda also completed her master's degree using Voyager 1 and Voyager 2 data on the Cassini and Encke Divisions in Saturn's rings for her thesis. Her studies of Saturn's D ring are being applied to the new ring systems at both Uranus and Neptune. In between these encounters Linda plans to get her Ph.D.

Ellis Miner, deputy project scientist for Voyager, says: "I feel like a kid that's been given a new toy and is just beginning to see the things that that toy can do." Ellis believes each new discovery is stimulating enough to make all the time that's gone into Voyager's planning worthwhile. He adds that Voyager has made his job much more enjoyable than he could have ever expected. During encounter, the seven-day weeks and fourteen-hour days flew by without notice.

For Ellis, the most interesting findings at Uranus included the presence and tilt of the magnetic field (it is tipped 55 degrees from the axis of Uranus' rotation), the electro-glow of the planet (atmospheric glow of Uranus), the tectonic features on Ariel, the absence of small particles in the ring plane, the complexity of those rings, the ten new satellites, the composition of the pre-Voyager moons, and, of course, the geological variety of Miranda.

The atmosphere at JPL during the Uranus encounter was a happy one; anticipation filled the air. The Voyager team took up residence for the duration and worked continually on their data. Someone calculated that the team consumed 3,200 doughnuts during encounter. At closest approach, there was jubilation, happy faces, and champagne. Then everyone got a few hours sleep and went back to their data.

The Voyager 2 success at Uranus left the team with a feeling of euphoria. Then, in an instant, as many of the team watched the Challenger liftoff on television, they were devastated. The Challenger tragedy hit JPL hard. It was a tragic human loss — a personal loss. Against the crescent backdrop of receding Uranus the team mourned for the astronauts and their families. Characteristically, though, shock gave way to strong resolve — a commitment to do an even better job at Neptune.

The Voyager team had already had its own troubles. Doug Griffith, manager of the Flight Operations Office, says that in a crisis situation "you really get pumped up and the adrenalin flows. Everyone pulls together to get the job done."

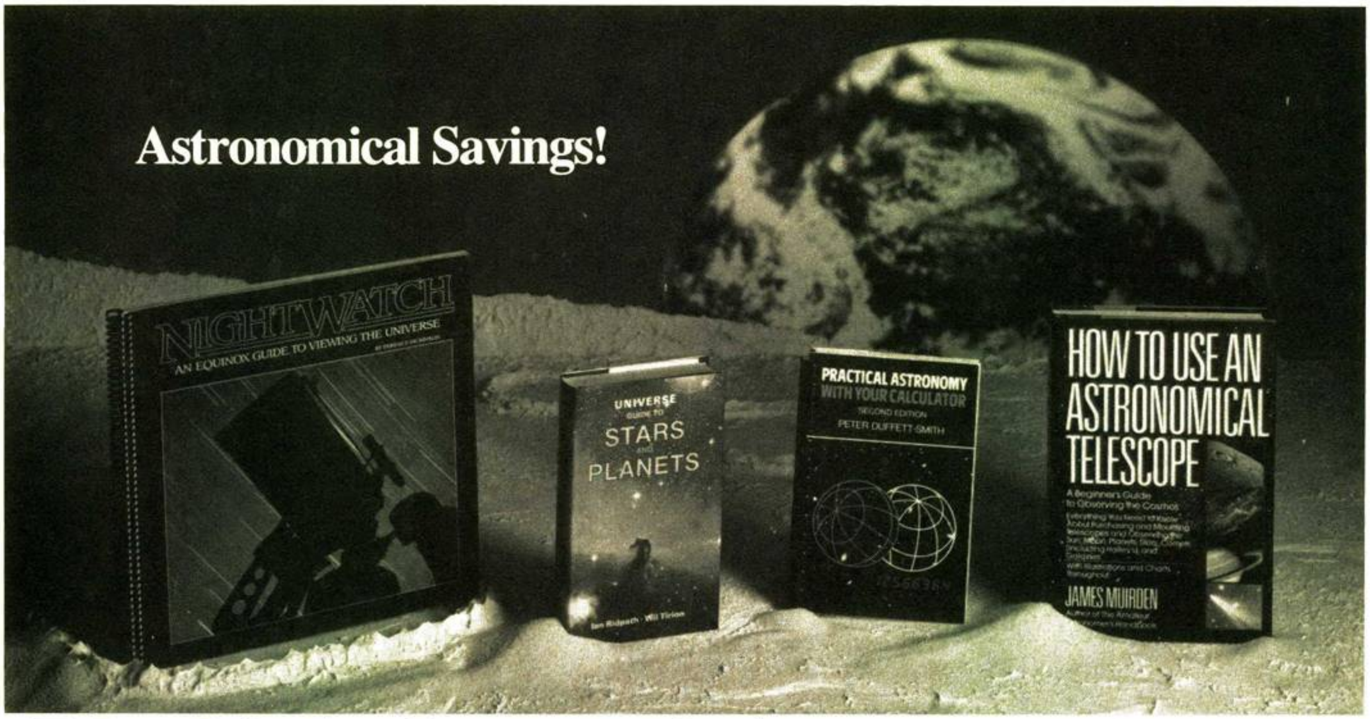
Five days before the Uranus encounter an anomaly was discovered in the Voyager data; project engineers and scientists were quickly called together. "Within a few hours, a sequence was designed to interrogate the spacecraft and the procedure was decided on to conduct that interrogation," says Doug. Within a day, the problem was found. A single memory cell in the flight data subsystem had failed — a failure that would have resulted in flawed pictures of Uranus. A scheme was developed to patch around the problem.

"I feel like a kid that's been given a new toy and is just beginning to see what it can do."
— Ellis Miner

According to Doug, all of this was a "total team effort on the part of Operations, Ground Systems, Spacecraft, Image Processing, Science, and Sequencing Teams." The feeling was one of exhilaration at being able to function so well as a team. "This was the best encounter yet," says Doug. "Things could not have gone better."

Don Gray, Voyager Navigation Team chief, says Voyager "created an atmosphere of excitement and discovery around the Jet Propulsion Laboratory." He adds that there have been surprises at every encounter. For the Navigation Team there have been times when "you think you've got the orbit determined and all of a sudden your data starts running away from you . . . Sometimes you have to make decisions based on data that are not as precise as you would like them to be. But at these times a decision has to be made, and sometimes it amounts to an educated guess."

"Voyager shows that the human imagination is still alive," says Charley Kohlhase. Imagination allows people to



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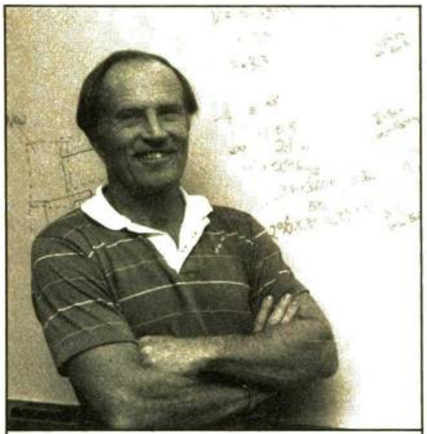
Astronomy 5/86

stand aside from their day-to-day problems and see things in a much larger perspective.

"Voyager was worth the two dollars per person in the United States that it cost just to have the pictures of Jupiter, Saturn, and Uranus," says Steve Synnott. "How could anyone who has any sense of nature not be moved by the spectacular color display of Jupiter, the incredible complexity of Saturn's ring system, and the stark cold beauty of the Uranian system?"

For Linda Horn, Voyager tells the world that "we're not afraid to take on a challenge."

"The space program has done more to stimulate the growth of human knowledge than any other aspect of life on Earth," claims Ellis Miner. "The spinoffs we have received have returned around fourteen times the money back into the economy that was originally spent."



"People will see this as a landmark era just as exciting as the exploration of our nation." — Don Gray

According to Doug Griffith, Voyager is "a fabulous achievement for mankind, one of the greatest single achievements of the space program." He adds that it has taught us a lot about comparative planetology and how to make Earth a better place to live.

Don Gray likens the Voyager explorations to those of Columbus and early pioneers who explored the American wilderness. If there is a message Voyager can give the nation, it is that "*there is no* other nation on Earth with the capabilities that this nation has developed to go explore the outer planets. When people look back two or three generations from now they will see this as a landmark era, an era just as exciting as the exploration of our nation."

— *John Graham*
Newport Beach, CA

From Spectator to Astronomy Club Convert

How does someone who thinks a parsec is only a term from *Star Wars* become transformed into a compulsive amateur astronomer? Mainly through the efforts of a dedicated amateur astronomy club.

Early in 1984, I started reading articles about the return of Halley's Comet. The articles led me to books about comets and to an increased awareness of things astronomical.

My introduction to amateur astronomy, however, really began when I took my seven-year-old daughter to Astronomy Day '85 at our local planetarium. The area astronomy club had telescopes set up outside for solar viewing, and they were even letting the public take pictures through them. My daughter climbed up a ladder to one of the scopes for a look at the Sun. She was not as excited as I was; to her, it was just round and yellow. But I, who had hundreds of times repeated, "Don't look at the Sun, you'll be blinded," was fascinated! I really was looking at the Sun! Obviously astronomy included more than comets.

Next my daughter took a course at the planetarium. As chauffeur, I sat in on the classes and became more and more interested. In fact, I had to refrain from asking more questions than the kids. My interest in the Sun and stars began long ago in grade school, but there had been no classes, no astronomy club to provide slide shows in schools or at public star parties, and no Astronomy Day. I realized anew why astronomy is stimulating: there is always something to wonder about and always something to learn.

We eagerly awaited the club's next public star party. In preparation, I checked out library books on astronomy and purchased back issues of ASTRONOMY and *Odyssey*. The night of the star party we saw the Moon, viewed Saturn with its beautiful rings, and observed Jupiter and its moons. One man told us about Galileo and how he had suffered for his discoveries. Another member used his flashlight to point out different stars and constellations. My daughter and I were both impressed.

My final plunge from interested observer to active club member came in the shape of a used Edmund 6-inch telescope, which I bought at a secondhand store. After finding one of the club's newsletters that I'd saved from a past star party, I called the president. I asked him whether he or anyone else could evaluate this telescope for me. Not only did he say he would, but he suggested that I attend a class that night for new club members. The topic was "How to Choose Binoculars or a Telescope"!

That evening after the class, different club members looked at my Edmund scope. Out came a 1966 Edmund catalog showing a similar telescope. The members talked about it fondly, as though it were an old high school friend they had all known. Someone said they could fix the drive motor, and somebody else inspected the mirror. Meanwhile, I sensed that I hadn't bought just a telescope but a whole new lifestyle.

We took the scope outside and looked through it. I saw Jupiter gleaming softly at me in the dark sky. That night, I dreamt I was orbiting Jupiter — a strange dream — but I woke up feeling very happy. I was hooked on astronomy.

I showed up for the next five classes in the club's series. These covered using star charts, building a Dobsonian telescope, astronomy books and charts, training your eye, and eyepieces. The classes were invaluable for us beginners. Not only did they increase our knowledge quickly, they also saved us from a lot of frustration and unwise purchases. Club members brought in all kinds of telescopes, eyepieces, and books for us to examine. They answered questions, drew diagrams, and helped us select materials appropriate to our interests and experience.

The seasoned members took great pains (I'm sure pain is the correct word) to include new members on club outings. They spent extra time providing directions and helping us learn how to use our telescopes. The club also provided a 12-inch telescope for everyone to share, and veteran members let us novices look through their own scopes.

The star parties have been wonderful, but best of all the club has given me friends with whom I can share my enthusiasm. It is disheartening to finally find M13 — only to have a non-astronomer friend say, "Oh, that little blob? Fuzzy, isn't it?" I'd much rather be out on a dark mountain top with people who shout when they see a meteor, who are still enchanted by the Orion Nebula (no matter how many times they've seen it), and who — after five, eight, or fifteen years of observing — are still learning and are still excited about the universe. That adds up to a club worth belonging to and working for!

C.S. Shelton
Eugene Astronomical Society
Eugene, OR

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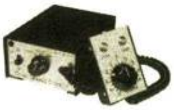

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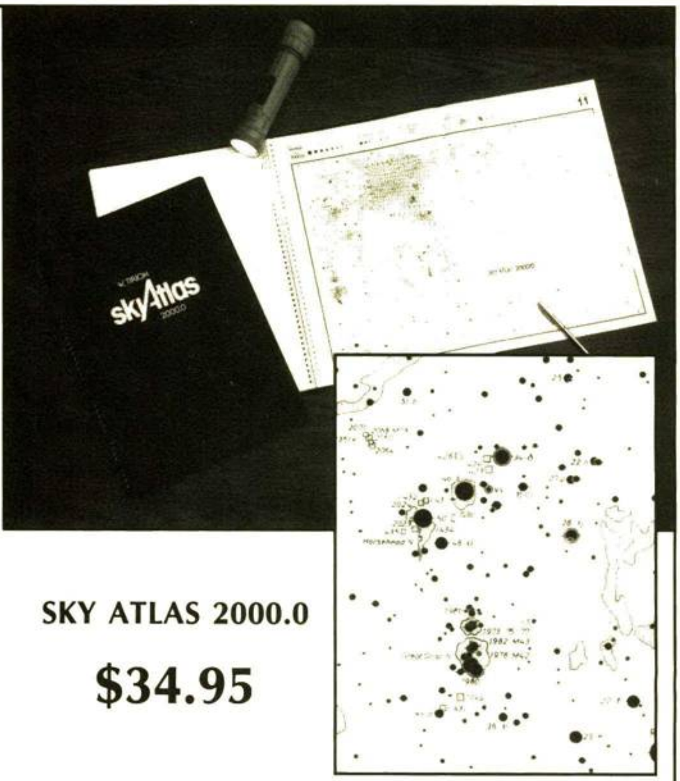

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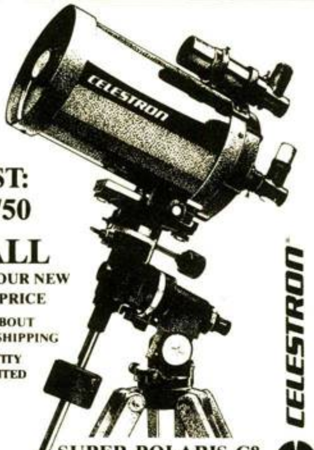

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ASTRONOMY
In Focus

After the Shuttle

Sir / Like many people, I have spent these past few days trying to sort out my feelings. Terrible things happen to people all the time. Yet the Challenger tragedy hit a special chord. The "Challenger 7" sought the fulfillment of a dream that I and all the readers of ASTRONOMY can relate to: exploring the heavens. Given the chance, I would gladly go on a Shuttle mission. Before the day of the tragedy, I would have thought — as Christa McAuliffe and her six colleagues must have — that danger was involved, but after so many successful flights it seemed minimal. Today we know the danger still exists.

I cannot pretend to know what it is like to be one of the relatives or friends of the seven whose lives were cut short. But I do feel that I've lost something along with them, for it is a love of the universe that unites those of us who share that love. In that respect, all of us lost seven friends in that explosion.

But even as we grieve, we know we must go on. Otherwise, their deaths were in vain. Let the space program continue. Let's show that their lives and untimely deaths were part of a larger, successful crusade: the exploration of the universe.

Stephen Cerone
Westfield, NJ

"B" Values vs. Magnitudes

Sir / In the January 1985 issue, you printed an article titled "Exposure in Astrophotography" that gave a formula for calculating the approximate exposure time for a given film and focal ratio. The formula calls for a brightness, or "B" value, for various celestial objects and included a fairly complete table of "B" values in the article. This formula makes neophytes like myself feel more comfortable with astrophotography.

However, there's a small problem. Most astronomical information I have seen lists the magnitude of celestial objects but not a "B" value. Is there a direct mathematical relationship between the two? If so, can you tell me what the "B" values will be for Comet Halley in 1986?

William L. Dombo
Cerritos, CA

— "B" values are a measure of the surface brightness of an extended object whereas magnitude is a measure of an object's total brightness. Providing you know the angular size, you can find the surface brightness by dividing the object's total brightness by its surface area. However, since magnitude is based on a log scale you must first linearize brightness. The formula for calculating B is:

$$B = \frac{10^{0.4\,(9.5 - M)}}{D^2}$$

where M is the magnitude of the object and D is its angular diameter in seconds of arc. This assumes, of course, that the object is round. The following BASIC program will print the "B" value given M and D.

```
10 REM B-VALUE PROGRAM
20 INPUT "MAGNITUDE";M
30 INPUT "DIAMETER IN
SECONDS";D
40 B = 10^(0.4*(9.5-M))/D/D
50 PRINT "B-VALUE = ";B
60 PRINT:GOTO 20
```

Jupiter, for example, will have a magnitude of −2.9 this winter and a diameter of 48 arc-seconds. These numbers yield a B value of 39.

Comet Halley presents problems: It is a diffuse object, its light is unevenly distributed, and furthermore, it will not be round when it has a tail. You can still get a rough idea of the "B" value, though. Suppose the comet reaches 2nd magnitude. If the coma is 1,000 seconds of arc (a bit over 1/4°) in diameter, then "B" is 0.001. If the diameter is 1°, then "B" is 7 x 10^{-5}*. In both cases, the "B" value lies between that of a bright deep-sky object and the surface brightness of the night sky.*

Accolade for "Christmas in August"

Sir / While I rarely write to the editor of a magazine, I cannot resist complimenting you on the excellent article "Christmas in August" (In Focus, January 1986). It was perceptive and well written and does honor to your publication.

Articles like this are welcome additions to the hard science and how-to features; they're a pleasant reminder as to why we all do this: for the mystery and intrigue found in the night sky.

Ron LaFon
Petaluma, CA

Light Pollution Crusaders: Where Will They Stop?

Sir / I am a resident of the San Fernando Valley and have lived here all of my 23 years. I don't know about all these observing problems I'm supposed to be having (In Focus, March 1986). My 4-inch refractor and 10-inch Dobsonian provide many fine views of the heavens from my backyard.

I think these "anti-lighters" are narrow-minded and more than a bit selfish. The starry sky is beautiful, but so is Los Angeles at night.

I imagine there will soon be a "Pro-Ultraviolet" movement composed of stargazers who want to eliminate Earth's living creatures because they can't do ground-based UV astronomy through all of our biological emanations. One day, there may even be the ultimate astronomical movement: the "Anti-Twinkle" campaign. The battle cry will be "Remember how stars seemed so much sharper back in the old days before Earth had an atmosphere?"

David Epstein
Encino, CA

Establish "Dark" Areas

Sir / The growing problem of light pollution invading our dark rural skies must be combated by establishing "National Dark Areas." These astronomy vistas could be developed in our national forests and parks or in other areas far from civilization.

An organization should be formed to promote and lobby for these areas and a fund established to campaign for skies free of light pollution.

If the trend of more light for growing cities continues, this could prove our last chance for saving one of nature's greatest spectacles: a truly dark natural sky.

Glenn Mac Dougall
Daly City, CA

A Road Less Traveled

Sir / I am sorry to tell Ted Pelin (In Focus, March 1986) that he was not the first of "us over eighty-year-olds" to see Halley's Comet twice.

My five-year-old great-grandson Ted and I saw the comet at about 10 p.m. EST on November 8, 1985, through the 14-inch telescope in the observatory operated by the Passaic County Park Commission in West Paterson, New Jersey.

I was six when I saw Halley's Comet in the spring of 1910, and I don't think I would have remembered it were it not for the interest my Uncle Otto had in the natural world and the heavens. We lived on my grandfather's farm in Paterson, New Jersey, and my father, my uncle, and I climbed the hill east of the farm to see it in the early morning hours.

The sight made such an impression on me that my first Boy Scout merit badge was in astronomy, which also led me to study meteorology and seismology. I think astronomy guided the whole course of my life.

Although I never became a professional in any of the hobbies that I pursued through the years, the initial surge of interest begun by seeing Halley's Comet led me down a road "less traveled" and it actually has, as poet Robert Frost said, "made all the difference."

Philip J. Del Vecchio
Paterson, NJ

Expanding Your Horizons

Sir / I'm writing to tell you about a cure for the common question: "What is there to look at tonight?"

The following situation probably sounds familiar to a lot of amateur starwatchers. It's the first good, clear night after a long spell of bad weather and you can hardly restrain your gasps and wows as you see the stars for the first time in weeks. Without hesitating, you cart your telescope outside. After checking out everything on your must-see list, you stand in frustration, thinking what can I look at next? The observing time you've been waiting so long for is about to be wasted.

I used three generations of telescopes before developing a cure. Using a set of AAVSO charts, I decided to commit them to general use for plotting everything from comets to elusive galaxies.

A problem that not every stargazer might fancy is taking their library out observing. The answer is a reference catalogue taken from several books and compressed into one easy-to-carry file. I compiled data from ASTRONOMY's constellation maps, Hartung's *Astronomical Objects for Southern Telescopes*, the *Revised NGC*, and the *Cambridge Deep-Sky Album*.

The opportunity to try out my efforts came on a Sunday night last December. I had one hour to observe before the Moon rose; I decided to split all the double stars in Canis Major using the catalogue and charts. I managed to split 9 out of 10 that I tried. One of those even rivaled Alberio!

My experience illustrates that, with thorough preparation, there are enough objects within reach of small telescopes that observers should never conclude they've seen them all. I hope other observers will also search out lesser-known objects and expand their observing horizons.

A. Engelbrecht
Jacobs, South Africa

Behind the Scenes

"A Difficult Thing"

When Challenger exploded we, as a nation and as individuals, were stunned into silence and disbelief. Those of us watching the liftoff at the Jet Propulsion Lab in California, where I was covering the Voyager flyby of Uranus, stared blankly at the television screens showing first the fireball and then that huge white "Y" against a deep blue sky.

It's gone. They're gone. No one could have survived that. Nothing came out of that fireball in one piece. Gone. It didn't happen. It did. It couldn't happen. It did.

Some reporters grabbed for telephones. Others wept. Yet even as the human dimensions of the tragedy began to sink in, the long-term implications for the whole space program dawned on us. Ulysses? Galileo? Space Telescope? What now?

A month later, these questions remain unanswered. We've learned about O-rings and booster seals. We follow the investigation of a "flawed decision process" as people testify to what they didn't know or didn't tell.

We received many letters from you, our readers, expressing your feelings on that tragedy. We have chosen to publish only one, taken almost at random, to speak for all of you.

On a different note, we're sorry to announce that Senior Editor Robert Burnham has left ASTRONOMY and headed for the dry air, sunny days, and dark skies of the southwestern deserts. Robert had been with the magazine for seven years, and has been a friend of mine for many years more. Robert will continue writing for ASTRONOMY; he has agreed to take on "Eye on the Sky," our monthly naked-eye observer department.

Despite Robert's leaving, ASTRONOMY's staff is growing. We've added two assistant editors. Jeff Kanipe hails from Austin, Texas, where he had been making his living for the last four years as a freelance writer. Readers of the McDonald Observatory News will recognize his byline from "Between the Stars"; Jeff has also written scripts for the Star Date radio show. His first story for ASTRONOMY appeared last month.

Our second new editor is Richard Talcott, an astronomy teacher from the Physics Department of Marietta College. A few of our southeastern Ohio readers may have attended one of his Halley's Comet lectures. Rich's math background led him into computer programming for several years, and now his lifelong fascination with astronomy has led him to us in Milwaukee.

Sincerely,

Richard Berry

Richard Berry
Editor-in-Chief

Let's talk prices.

And stripping, and shipping, and is it in stock?

Let's be honest about telescope buying for a minute. A low advertised price on a telescope doesn't do you much good if the dealer doesn't have the scope in stock at the advertised price; or if he makes up for that low price by slapping on unexpected service or handling charges or by overcharging you on freight and accessories; or if he strips factory-standard parts (such as finders and eyepieces) from the telescope before shipping, claiming they're options and charging you extra for them; or if he uses your money for months while you wait in vain for your telescope or a refund.

At Ad-Libs Astronomics, we have low prices on telescopes and accessories all the time, with no hidden charges. The prices you see below are all you pay. And we have telescopes and accessories *in stock* — hundreds of telescopes and thousands of accessories — so we can ship *now*. And we don't strip out essential parts before shipping — we give you every piece the manufacturer supplies. And we give you free freight within the 48 states if you pay by check or money order. Even if you put your scope on Visa, Mastercard, or American Express, we only charge you the freight that UPS charges us. (The credit card freight on a Celestron SP-C8 to either New York or California is only $28.25. We've heard that some dealers charge as much as $125!)

The prices below are just a small sampling of the great telescope and accessory values you'll find at Ad-Libs Astronomics. Our free discount price list has hundreds more. Write for it today.

Want a good price on accessories or on a quality Celestron, Meade, Edmund, Bausch & Lomb, Questar, or TeleVue telescope — one that comes with *all* accessories, *free freight*, and can be shipped *now?* We have what you want. Just look . . .

BAUSCH & LOMB TELESCOPES

Product	Description	List	Price
034	Criterion 4000 4" Schmidt, drive, table tripod	$950.00	$549.00
035	Criterion 4000E, with enhanced aluminum mirrors	980.00	579.00
040	Criterion 4000 Professional	1070.00	649.00
037	Criterion 6000 Professional	1600.00	1045.00
	■ Criterion 6000 Professional, wedge, tripod	2070.00	1369.00
039	Criterion 8000 Professional	1925.00	1299.00
	■ Criterion 8000 Professional, wedge, tripod	2395.00	1619.00

CELESTRON TELESCOPES

Product	Description	List	Price
	COMETRON REFRACTORS		
062	CO-50B 2" brass decorator scope, mount	$600.00	$399.00
067	CO-60E 2.4" f/15 equatorial, tripod	600.00	399.00
	COMETRON REFLECTOR		
057	CO-114 4½" f/8.75 Newtonian, tripod, equatorial mount	750.00	499.00
	CELESTRON REFRACTORS		
073	Firstscope 80 3.1" f/11 altazimuth, tripod	800.00	549.00
074	C80 3.1" f/11 equatorial, tripod	1250.00	799.00
075	SP-C80 3.1" f/11 Super Polaris equatorial, tripod	1400.00	899.00
079	SP-C102 4" Super Polaris equatorial, tripod	2000.00	1299.00
2358	Super Polaris Sky Sensor computer, if bought w/scope	700.00	379.00
	CELESTRON REFLECTORS		
083	5½" f/3.64 Comet Catcher Schmidt-Newtonian	600.00	399.00
086	C6 6" f/5 Newtonian, tripod, equatorial mount	1250.00	799.00
087	SP-C6 6" f/5, Super Polaris equatorial, tripod	1500.00	949.00
2358	Super Polaris Sky Sensor computer, if bought w/scope	700.00	379.00
	CELESTRON SCHMIDT- AND MAKSUTOV-CASSEGRAINS		
096	SP-C8 8" Schmidt, Super Polaris mount	1750.00	1099.00
099	SP-C8, special coatings, Starbright silver mirrors	2100.00	1299.00
2358	Super Polaris Sky Sensor computer, if bought w/scope	700.00	379.00
102	Super C8 Plus, coatings, fork mount, Beyers drive	2400.00	1499.00
	■ Super C8 Plus, with wedge and tripod	2930.00	1849.00
106	Super C8 Plus, with Starbright silver mirrors	2600.00	1649.00
	■ Super C8 Plus Starbright, with wedge and tripod	3130.00	1999.00
112	C11, with special optical coatings	5400.00	3399.00
	■ C11, with coatings, wedge and tripod	6970.00	4399.00
113	C11, with Starbright mirrors and special coatings	6000.00	3799.00
	■ C11 Starbright, with wedge and tripod	7570.00	4799.00
116	C14, with special optical coatings	12,300.00	*6749.00
	■ C14, with coatings, wedge and tripod	13,870.00	*7749.00
117	C14, with Starbright mirrors and special coatings	12,900.00	*7149.00
	■ C14 Starbright, with wedge and tripod	14,470.00	*8149.00

EDMUND TELESCOPES

Product	Description	List	Price
132	2001 Astroscan 4" RFT	$299.00	$239.00

ACCESSORY CASES/TOTE BAGS

Product	Description	List	Price
206	Bausch & Lomb accessory case	$39.95	$32.50
205	Celestron 5¼" × 10" × 13½" case	50.00	37.50
210	Celestron Comet Catcher case	70.00	52.50
220	Tote bag for Edmund 2001	24.95	22.95
4560	Anti-skid mat for Astroscan		6.95

ASTROCAMERAS/ACCESSORIES

Product	Description	List	Price
	OLYMPUS		
531	OM-1 body, screen, cable, T-ring	$379.45	$254.95
530	OM-1 body only	330.00	209.00
540	Varimagni finder	113.50	82.50
547	Planetary focusing screen #1-7		27.50
548	Deep space/terrestrial screen #1-8		27.50
550	Olympus f/1.8 prime lens	105.00	74.95
552	Olympus f/1.4 prime lens	180.00	134.95
560	Locking cable release		6.50

1¼" BARLOW LENSES

Product	Description	List	Price
	BAUSCH & LOMB		
705	2x Barlow	$39.95	$32.50
	CELESTRON		
710	2x Barlow	60.00	44.50
715	2x deluxe Barlow	100.00	74.50
720	3x Barlow	60.00	44.50
	EDMUND		
726	2.5x RKE Barlow	46.95	39.95

.965" BARLOW LENSES

Product	Description	List	Price
810	Celestron 2x Barlow	$50.00	$37.50
815	Celestron 2.5x Barlow	50.00	37.50
820	Celestron 3x Barlow	60.00	44.50

2" BARLOW LENS

Product	Description	List	Price
910	Celestron 2x Barlow	$100.00	$74.50

BINOCULARS

Product	Description	List	Price
	CELESTRON COMETRON		
1131	7 x 35mm wide angle	$80.00	$59.50
1146	7 x 50mm Comet Watcher	100.00	74.50
1189	12 x 50mm high power	110.00	82.50
	CELESTRON		
1122	8 x 30mm Nova extra light	200.00	140.00
1135	7 x 35mm extra-wide classical	160.00	115.00
1140	7 x 35mm Nova wide angle	280.00	190.00
1145	7 x 50mm extra-wide classical	180.00	125.00
1155	7 x 50mm Nova wide angle	300.00	210.00
1160	10 x 50mm classical	200.00	140.00
1165	10 x 50mm Nova high power	350.00	240.00
1167	Deluxe 16 x 70mm astronomical	460.00	299.00
1170	11 x 80mm astronomical	460.00	299.00
1175	20 x 80mm astronomical	470.00	309.00
1176	Deluxe 20 x 80mm astronomical	750.00	479.00
1180	30 x 80mm astronomical	480.00	319.00
1185	Binocular tripod adapter	30.00	22.50

CAMERA ADAPTERS

Product	Description	List	Price
1305	T-C 16mm/video adapter	$50.00	$37.50
1311	Edmund 1¼" prime focus adapter		7.95
1312	Edmund variable sliding tube adapter	44.95	39.95

COLD CAMERA

Product	Description	List	Price
1505	Celestron 35mm cold camera	$600.00	$399.00

COUNTERWEIGHTS

Product	Description	List	Price
	BAUSCH & LOMB		
1701	Criterion 6000/8000 cwt. set	$59.95	$49.95
	CELESTRON		
1705	C90/C5 counterweight set	80.00	59.50
1710	C8 counterweight set	80.00	59.50
1715	C8 counterweight bar assembly	150.00	112.50
1720	C11 counterweight bar assembly	150.00	112.50

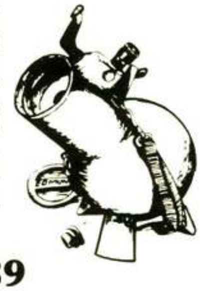
DEWCAPS AND LENS SHADES

Product	Description	List	Price
	CELESTRON		
1920	Dew cap for C8	$80.00	$59.50

DRIVE CORRECTORS

Product	Description	List	Price
	CELESTRON		
2319	Quartz single axis for C5/8/11	$400.00	$289.50
2320	Quartz dual axis for C5/8/11	500.00	349.50
2330	Bracket to use dual axis on C5	30.00	22.50
2335	Bracket to use dual axis on C11	40.00	29.50
2340	Heavy duty drive corrector	800.00	599.50
2350	DC inverter	160.00	119.50
2355	Pulse motor/drive corrector	240.00	179.50
2356	Super Polaris single axis motor	200.00	149.50
2357	Super Polaris dual axis motor	320.00	239.50
2358	Sky Sensor computer/drive	700.00	399.50
2359	AC power supply for Sky Sensor	150.00	112.50

Edmund Astroscan: a rich field telescope with a 3° field of view for effortless wide-field deep sky observing. With 16x 1¼" RKE eyepiece, peep sight finder, rubber eyeguard, dust cover, carry strap, altazimuth base, and Sky Guide.



~~$299.00~~ **$239**

All products are normally in stock, subject to unexpected manufacturers' backorders beyond our control.
All prices are good through May 31, 1986.

MOTO-FOCUS ELECTRIC FOCUSERS

Product	Description	List	Price
2401	Focuser for Celestron refractors	$119.95	$89.95
2402	Focuser for Celestron C5/C8	119.95	89.95
2403	Focuser for pre-1977 Celestron C8	119.95	89.95
2404	Focuser for Celestron C11/C11	129.95	98.50
2405	Focuser for Meade 2080/2120	129.95	98.50
2406	Focuser for Newtonian reflectors	119.95	89.95
2407	Focuser for TeleVue Renaissance	119.95	89.95
2409	Deluxe focuser for Celestron C14	189.95	149.95

EQUATORIAL MOUNTS

Product	Description	List	Price
2525	Comet Catcher equatorial mount	$900.00	$599.00
2526	Super Polaris equatorial mount	950.00	649.00
2530	Celestron Super Polaris half pier	150.00	112.50
585	Celestron STELAS drive	160.00	119.95

EQUATORIAL WEDGES

Product	Description	List	Price
2501	B & L 6000/8000 wedge	$130.00	$97.50
8901	B & L 4000 photo tripod wedge	119.95	89.95
2502	B & L 4000 polar alignment kit	39.95	32.50
2510	Celestron wedge for C5/8	130.00	97.50
2515	Celestron wedge for C11/14	700.00	499.50
2520	Celestron C8 deluxe latitude adjuster	60.00	44.50

1¼" EYEPIECES

Product	Description	List	Price
	BAUSCH & LOMB		
290100	Plossls (specify focal length)	$90.00	$69.50
	(Available in 10, 17, 26, and 35mm.)		
	CELESTRON		
290000	Erfles (specify focal length)	100.00	74.50
	(Available in 16, 20, 24, 28, and 32mm.)		
291000	Orthoscopics (specify focal length)	80.00	59.50
	(Available in 4, 5, 6, 7, 9, 12, 18, and 25mm.)		
291500	Plossls (specify focal length)	120.00	89.50
	(Available in 7.5, 10, 15, 17, 22, 26, 36, and 45mm.)		
	EDMUND		
292000	RKE (specify focal length)	32.95	29.95
	(Available in 8, 12, 15, 21, and 28mm.)		

.965" EYEPIECES

Product	Description	List	Price
	CELESTRON		
300500	Kellners (specify focal length)	$60.00	$44.50
	(Available in 18, 25, 30, and 40mm.)		
301000	Orthoscopics (specify focal length)	70.00	52.50
	(Available in 4, 5, 6, 7, 9, and 12mm.)		

ZOOM EYEPIECES

Product	Description	List	Price
	CELESTRON		
3205	1¼" 8.4mm to 21mm ortho	$150.00	$112.50
3210	.965" 8.4mm to 21mm ortho	120.00	89.50
3215	Deluxe .965" 9.5mm to 21mm ortho	180.00	129.50

FILTER ADAPTERS

Product	Description		Price
3405	Celestron 1¼" filter adapter	$30.00	$22.50
3410	Celestron .965" filter adapter	20.00	17.95
3415	Celestron 2" filter adapter	20.00	17.95
3420	Celestron Chromestar filter wheel	180.00	134.50

FILTERS, PHOTOGRAPHIC

Product	Description	List	Price
	CELESTRON		
3605	Series 5 drop in filter set	$70.00	$52.50
3606	Series 6 drop in filter set	80.00	59.50
3632	Skylight filter, Model 2	60.00	44.50

FILTERS, VISUAL

Product	Description	List	Price
3701	Celestron 1¼" eyepiece filter set	$90.00	$67.50
3702	Celestron .965" eyepiece filter set	80.00	59.50
3703	Celestron 2" eyepiece filter set	130.00	97.50
3631	Celestron skylight filter, Model 1	60.00	44.50

FINDERSCOPES

Product	Description	List	Price
	CELESTRON		
3907	Polar axis finder	$100.00	$74.50
3910	Right angle 5 x 24mm for C90 C5	60.00	44.50
3915	Right angle 6 x 30mm for C8	80.00	59.50
3921	8 x 50mm w polar reticle for C8	200.00	149.50
3923	8 x 50mm w polar reticle for C11	200.00	149.50

ILLUMINATED RETICLE EYEPIECES

Product	Description	List	Price
4305	B & L 9mm 1¼" ortho	$119.95	$89.95
4310	Celestron 12.5mm 1¼" ortho	160.00	115.00
4315	Celestron 1¼" projection reticle	220.00	159.50
4320	Celestron .965" projection reticle	190.00	139.50

Celestron Super C8 Plus: with Starbright silver mirrors, high transmission coatings, wedge, adjustable height tripod, Byers worm gear drive, two 1¼" eyepieces (26mm Plossl and 7mm ortho), 8 x 50mm illuminated polar axis finderscope, deluxe latitude adjuster, Star Watch book, Deep Sky magazine subscription, instruction cassette, and much more. ~~$3130.00~~ **$1999**

CELESTRON

NEBULAR FILTERS

Product	Description	List	Price
	BAUSCH & LOMB		
4700	Series 6 drop in filter	$99.95	$79.50
	CELESTRON		
4701	LPR #1 for visual back	150.00	109.50
4702	LPR #2 for C11 and C14	250.00	179.50
4703	LPR #3 for .965" eyepieces	90.00	64.50
4704	LPR #4 for 1¼" eyepieces	100.00	74.50
4705	LPR #5 for 2" eyepieces	160.00	109.50
4706	LPR #6 (set) for binoculars	170.00	119.50
4707	LPR #7 for astrophotography	170.00	119.50

OFF-AXIS GUIDERS

Product	Description	List	Price
5106 4305	Bausch & Lomb guider system	$199.95	$149.95
5106	Bausch & Lomb guider body only	99.95	74.95
5111 4310	Celestron guider system	300.00	224.50
5111	Celestron guider body only	150.00	109.50

OPTICS CARE

Product	Description	List	Price
4501	B & L optics cleaning kit	$29.95	$27.50
4505	Celestron optics cleaning kit	40.00	29.95
4570	Comet Catcher collimation tool	50.00	34.50

PIGGYBACK CAMERA MOUNTS

Product	Description	List	Price
	BAUSCH & LOMB		
5982	Paraxial mount for 4000	$29.95	$24.50
5980	Paraxial mount for 6000	49.95	37.50
5981	Paraxial mount for 8000	49.95	37.50
	CELESTRON		
5904	Piggyback for C8	70.00	52.50
5907	Piggyback for C11 14	70.00	52.50
5925	Tangent assembly for C8	440.00	329.50
5927	Frame to use tangent with C11	100.00	74.50
5928	Frame to use tangent with C14	100.00	74.50

POLARIZING FILTERS

Product	Description	List	Price
6101	Celestron 1¼" polarizing filter set	$80.00	$59.50
6102	Celestron .965" polarizing filter set	80.00	59.50
6105	Celestron 2" polarizing filter set	100.00	74.50
6111	Polarizing filter assembly	160.00	119.50

PORRO PRISMS

Product	Description	List	Price
6317	B & L porro prism	$59.95	$44.50
6310	Celestron 1¼" porro prism	70.00	52.50
6315	Celestron .965" porro prism	60.00	44.50
6320	Image erecting lens for Cometrons	30.00	22.50
6322	Celestron 1¼" image corrector	60.00	44.50
6327	Edmund porro prism for Astroscan	69.95	54.95

RICH FIELD ADAPTERS

Product	Description	List	Price
6510	Bausch & Lomb RFT adapter	$119.95	$89.95
6520	Celestron RFA, with 20mm Erfle	200.00	149.50
6525	Celestron Rich Field Lens	50.00	37.50
6530	Celestron 2" Widestar system	280.00	209.50

SOLAR FILTERS

Product	Description	List	Price
	BAUSCH & LOMB		
7171	Solar filter for Criterion 4000	$149.95	$112.50
	CELESTRON		
7101	3½" full aperture for C90	250.00	187.50
7114	2" off axis for C5	200.00	149.50
7118	2" off axis for Comet Catcher	200.00	149.50
7121	8" full aperture for C8	500.00	349.50
7124	3" off axis for C8	450.00	324.50
7131	5" off axis for C11	450.00	324.50
7135	8" off axis for C14	560.00	399.50

Super C8 Plus with Starbright coatings

SPOTTING SCOPES

Product	Description	List	Price
	BAUSCH & LOMB		
7560	4" Schmidt Super Spotter	$700.00	$429.00
	CELESTRON		
7501	C65 f 12.5 Gregorian Maksutov	300.00	199.00
7507	Big Eye 1000mm Maksutov	650.00	399.00
7509	C90 f 11 1000mm Maksutov	720.00	429.00
7510	Super C90, 1¼" accessories	798.00	479.00

STAR DIAGONALS

Product	Description	List	Price
7705	Celestron 1¼" aluminum mirror	50.00	37.50
7710	Celestron .965" prism	44.00	32.50
7715	Celestron 2" mirror	400.00	274.50
7717	Celestron 2" Widestar C8 mirror	180.00	134.50
7720	Celestron 1¼" multiple ocular holder	190.00	142.50
7725	Celestron .965" multiple ocular holder	180.00	134.50
7726	Celestron Twinstar dual viewing diag	400.00	299.50

T-ADAPTERS

Product	Description	List	Price
7905	B & L Cass. focus adapter for 4000	$29.95	$24.50
7910	B & L Cass. focus adapter 6000 8000	29.95	24.50
7930	Celestron T adapter	50.00	37.50
7935	Celestron T adapter for C 90	50.00	37.50
7940	Celestron Comet Catcher T adapt.	50.00	37.50
7942	Celestron Cometron T adapter	50.00	37.50

TELECOMPRESSORS

Product	Description	List	Price
8301	B & L 30mm f 5, lens only	$59.95	$47.95
8302	B & L 30mm f 7.5, lens only	59.95	47.95
8310	Celestron 30mm & extension tube	100.00	74.50

TELE-EXTENDERS

Product	Description	List	Price
8510	Bausch & Lomb eyepiece adapter	$29.95	$24.50
8515	B & L eyepiece projection tube	29.95	24.50
8525	Celestron tele extender	50.00	37.50
8527	Celestron refractor tele extender	60.00	44.50

TELEPHOTO LENSES

Product	Description	List	Price
	BAUSCH & LOMB		
8705	1200mm f 12 Schmidt	$550.00	$349.00
	CELESTRON		
8722	C90 1000mm f 11 Maksutov	650.00	399.00

TRIPODS

Product	Description	List	Price
	BAUSCH & LOMB		
8900	Field tripod wedge combination	$470.00	$339.50
8902	Criterion field tripod only	350.00	249.50
8904	Tripod wedge combination for 4000	225.00	167.50
	CELESTRON		
8910	Tripod for C11 C14	870.00	599.50
8915	Adjustable height tripod C5 8 90	400.00	279.50
8920	Photographic tripod	150.00	109.50
8935	Azimuth adapter for adjustable tripod	100.00	74.50
8940	Car window mount	120.00	89.50

VISUAL BACKS/EYEPIECE HOLDERS

Product	Description	List	Price
8510	Bausch & Lomb eyepiece adapter	$19.95	$18.95
9120	Celestron .965" visual back	50.00	37.50
9125	Celestron 1¼" visual back	50.00	37.50
9150	Celestron Large Accessory Ring (LAR)	30.00	22.50

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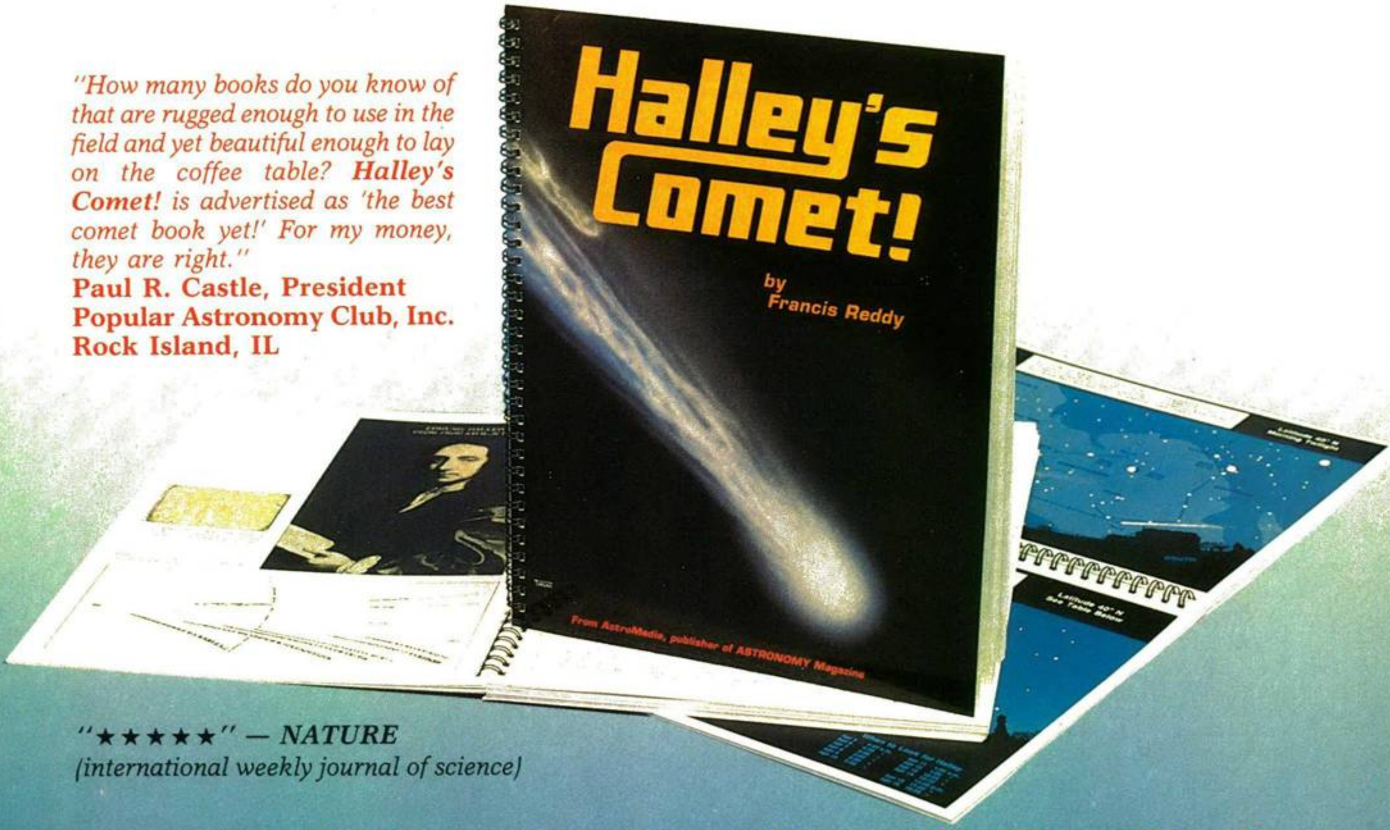

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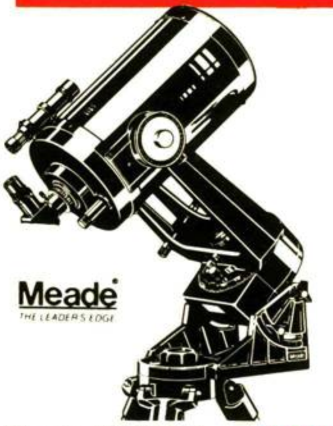

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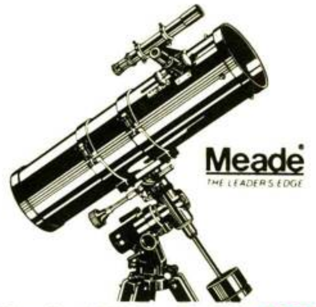

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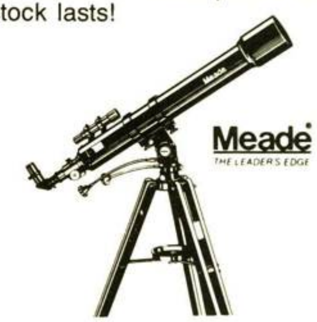

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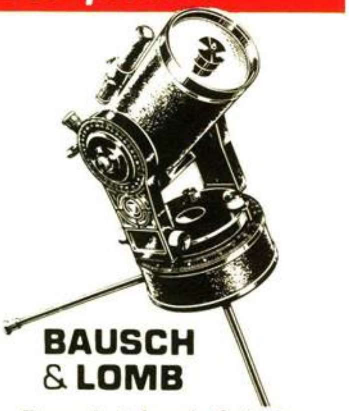

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ASTRONOMY
Reviews

. . . The Heavens and the Earth
Walter A. McDougall
555 pages, cloth, $25.95
Basic Books (1985)

McDougall writes at the beginning of his book: "I missed the first Moon landing. In July 1969 I had the night shift as chief of artillery fire direction in a particularly nasty jungle base in the III corps region of South Vietnam. A three- or four-day-old copy of *Stars and Stripes* told us of Apollo 11. I do not recall that it made much of an impression on us, except maybe to poke our ready sense of irony."

Books on the history of space flight generally seem to be written by people who are either fanatically for the endeavor or fanatically against it. Here is a history written by someone who appears to be truly neutral on the issue. The result is one of the best histories I have ever read and certainly the best regarding Soviet and American adventures in space.

Yet this book is not particularly *about* space exploration. It is about the history of our age and uses space development as an example of what the author calls the technocratic method, which he defines as "the institutionalization of technological change for state purposes, that is, the state-funded and -managed research and development explosion of our time."

McDougall believes it was the introduction of the technocratic method, beginning as early as the Civil War but not really getting underway until World War II and the Cold War, that spelled the beginning of the end for the pluralism that McDougall regards as the essence of the American Way. As he sees it, science and technology equate to power which, put into the hands of the state, is fundamentally incompatible with true freedom. He does not see this as a Republican or Democratic problem but rather the result of an alliance between both liberals and conservatives to use state power to manage technological and social change.

There's a lot in this thesis that I find very difficult to accept, even after spending three weeks reading 500 small-print pages of supporting material. But the real value of McDougall's work may lie not in his cultural theories but in the supporting material. His research, which includes vast quantities of early space-age documents declassified by the Freedom of Information Act, presents some truly remarkable insights.

Perhaps most remarkable is the idea that although the United States probably was not second in space on purpose, it wasn't too upset about it either. Apparently some members of the Eisenhower Administration felt that whatever happened in the future — arms control or an all-out arms race — it was necessary to break down Soviet secrecy. Therefore the United States' first space program was to have been a "spy" reconnaissance satellite.

However, many of Eisenhower's advisors felt that being snooped on from space might provoke the Soviets to begin a major conflict, perhaps even World War III. Hence the creation of Vanguard, an attempt to put a small and determinedly non-military satellite into an equatorial orbit that would not fly over Soviet territory. But ironically, the Soviets themselves established "freedom of space" with Sputnik.

McDougall considers the Soviet Union to be the world's first technocracy and he believes that it was competition with the U.S.S.R. that drove the United States in a similar direction. Why do the Soviets identify so with technology and with space technology in particular? "Revolution is a political program; to be a creed it must aim higher," McDougall writes. "The Promethean promise of Bolshevism is what stirred hearts; the conquest of Nature, not only of men and classes, is what inspired sacrifice . . . . [In] the decade of the revolution, before reality was apparent, Russian artists and revolutionaries alike dreamed of storming the cosmos and expected of it an apotheosis — as if the gods were false, but their heaven real."

In the chapter called "Parabolic Ballad: Khrushchev and the Setting of Soviet Space Policy," it's no surprise to find that Khrushchev fancied himself the man who would lead the Soviet Union into the technological glory of true communism. McDougall suggests that "this was a unique vision, the transition to pure communism could only happen once. No more would the U.S.S.R. be 'behind, but catching up' . . . . It was a daring vision, because if imperialist and counter-revolutionary demons were indeed exorcised, then failure to achieve the goal could only be blamed on the leadership itself."

In order to appear the superior nation Russia now had to *initiate* world events rather than simply react to them. Apparent leadership in space flight was the method Khrushchev chose. "By the time the bluff was called and Khrushchev dumped, the Soviets found they must return to the old formula: 'We are behind now, but . . .' even in the arena of their greatest triumph, outer space."

McDougall argues that the Soviets weren't the only political "rocket rattlers," for what else was Apollo? Even at the beginning of the program, many knew that the lunar orbit rendezvous method forced by Apollo's haste would prove "of limited future value to the space program; once current interest in lunar voyages flagged, the Saturns and Apollo craft would become extinct . . . . The Soviets, by contrast, never got to the Moon, but their Earth orbit rendezvous mode blended into an evolving space station program that sustained overall progress through the 1970s."

Written by an associate professor of history at the University of California in Berkeley, *. . . The Heavens and the Earth* represents a unique point of view on the early development of space flight. Yet the book is basically a conservative view that yearns for the world before technocracy and expresses deep misgivings for the ambitions of social engineers.

McDougall repeatedly states that the technological competition forced by the

Soviets upon the United States "may undermine the values which make a society worth defending in the first place. That, succinctly stated, is the dilemma of the Space Age." But the author admits, however, that technocracy is here to stay.

Invaluable as McDougall's book is as a history of the space program, as a history of the space *age* it fails to suggest any real solutions to the technocratic mess we may be in. The final chapters of this otherwise excellent book seem to degenerate into what appears to be a confusing (and possibly confused) defense of religion and a commentary on the "limits to science." McDougall commits the common error of believing that the entirety of the universe can be known through observations obtained from a single planet; since this has not happened, science has somehow "failed."

He argues that the liberal response to space flight is to feel "*pride and wonder* at man's *works* (the universe is our oyster) and *contempt* for man *himself* (we are inconsequential dust)." McDougall believes that the eventual impact of space flight will "teach us to have *contempt* for our *works* and *value* for *ourselves*," but he neglects to tell us how this will come about. (The emphasis is that of the original).

I see no incompatibility between being proud of one's accomplishments and recognizing their limitations. I confess I don't understand either the reasoning or the point of McDougall's concluding arguments.

Yet if anyone still wonders why they should read this book, the last chapter provides the answer: "We must ponder the ambiguities of the Space Age, because we have to live in it, willy-nilly." *Donald F. Robertson.*

Build Your Own Telescope
Richard Berry
276 pages, hardcover, $24.95
Charles Scribner's Sons (1985)

When telescope makers are asked for "plans" to a telescope, they often react just as I do: they stand there gasping like a fish out of water.

"You *do* have plans?" asks the admiring beginner.

Suddenly I'm cornered. I then have to admit that the closest thing I have to real drawings are contained in my head, and such plans are not available for public display. Sheepishly I have to explain that many telescope makers *don't build* telescopes so much as they give birth to them. Asking for plans is tantamount to asking a young mother for the "construction drawings" of her child.

Most telescope-making books reflect this orientation. They present telescope making in the broadest possible way and let readers design the instrument any way they want. They actually give readers more freedom than they can use. Beginners need a leg up to start with. They don't need endless possibilities but rather a firm, guiding hand; the creativity can come out in their *second* instrument.

Richard Berry has written a book that provides just that guidance. It gives assembly instructions for five specific telescopes: a 4¼-inch f/10.5 equatorial, a 6-inch f/8 Dobsonian, a 6-inch f/8 equatorial, a 10-inch f/6 Dobsonian, and a 6-inch f/15 alt-azimuth refractor. With the exception of the refractor, all are Newtonian reflectors and all feature simple woodworking in their construction.

I suspect that most readers will select either the 6-inch f/8 or the 10-inch f/6 Dobsonian. The 4-inch will be perceived as being too small, the refractor as too large and expensive, and the 6-inch equatorial as too difficult.

The Dobsonian mounting has become a standard in amateur telescope making. A decade ago Dobsonians were rare. A few people viewed them with disdain, saying loudly that they were ugly and would never be taken seriously. Five years ago they were still uncommon. Then enough people actually tried them and discovered that they *worked*. The large, smooth bearings made observing a pleasure. Ease of construction ensured that this design would be adopted by large numbers of budding telescope makers. It has been estimated that more than two out of every three home-built reflectors are now supported on Dobsonian mountings.

The 6-inch f/8 Dobsonian described in the book is a trim, inexpensive instrument. It is an *observer's* telescope. It won't win any awards at conventions, but if anyone wants a good basic telescope that can be thrown in the car and used regularly, this is it. I am sure that this telescope will quickly become scuffed and worn — sure signs that an instrument is loved. Its relatively slow focal ratio is extremely forgiving of misalignment and of aberrations in the eyepiece. Start with this telescope; by the time you decide to make a bigger one, you'll deserve it. (One thing I would add is an extra set of side bearings to direct the eyepiece to point up when looking near the horizon.)

A 10-inch f/6 Dobsonian is about the limit for a small reflector. Bigger telescopes require special transportation (the tubes no longer fit into cars easily) and special handling (two people usually). The seemingly small jump to 12 inches' aperture pushes the instrument beyond that limit; you'll be reminded every time you observe that the weight of a telescope goes up much faster than the aperture. Thus, this 10-inch is about as much telescope as a non-fanatic can handle.

The number of deep-sky objects easily visible through such an instrument is huge. (I once spent nearly a whole night using a 10-inch to look at galaxies in Cetus, one single constellation.) Brighter objects display a wealth of detail that eludes smaller telescopes. The 10-inch, unfortunately, is much more expensive to build than a 6-inch. If you are a beginner, a 6-inch makes more sense.

But don't reject the other instruments out of hand. The 4-inch is the neglected stepchild of amateur astronomy, giving images that seem as if they came from a much larger instrument. Manufacturers find it difficult to mess up this small mirror, and a 4-inch telescope is very inexpensive. Berry's 6-inch f/8 equatorial is starkly elegant. Its mounting is the extremely stable polar-plate equatorial, and its tube can be rotated for comfortable viewing. Lastly, I have actually used Berry's 6-inch refractor. To those accustomed to the typically shaky, undermounted refractor, this telescope is a revelation. It moves smoothly to each object and *stays* there.

The construction techniques in the book employ elementary woodworking methods that can be performed by any moderately handy individual with a garage and a few tools. Berry has conveniently marked off patterns for plywood so that little wood is wasted. This is in strong contrast to another prominent Dobsonian builder that I know. He begins at one end of a piece of plywood and cuts out pieces as needed until the unused wood collapses into an entropic jigsaw puzzle amidst great clouds of sawdust!

Berry also cleverly holds mirrors in place with silicone rubber adhesive. This material always seems too delicate to hold a mirror in place — until you attempt to remove the mirror. That plywood-destroying friend of mine convinces neophytes of this adhesive's ability by holding a silicone-glued mirror upside down over a concrete floor and shaking it brutally. Onlookers clench their teeth and avert their eyes, waiting for the inevitable smash, but nothing ever happens because that stuff holds *tight*.

Berry spends a couple of chapters on mirror making. Contrary to the usual orientation of telescope-making books, which dwell extensively on optical fabrication, this book concentrates on the mountings and adds a little material on mirror making. Don't be fooled by the length of the material, though. Some modern techniques of amateur mirror making are presented in book form for the first time. These include an advanced (yet easily built) Foucault tester, star-test retouching of Foucault-finished mirrors, and the lightning-fast Millies-Lacroix mirror evaluation technique. These methods have been around for years, but they were only written up in such ephemeral media as magazines or were passed around by word of mouth.

Naturally, the book suffers from the mistakes that seem to infest all first editions. The ones I caught included a mislabeled figure on page 34, which switched designations for the achromatic and apochromatic lens. Another more damaging error is in the figure on pages 206 and 207, where the labels for "deepening the edge" and "deepening the center" have been switched. The correct descriptions occur in the text, but people tend to prefer visual aids to translating words.

More fundamental is an error in the derivation Berry makes of the Millies-Lacroix tolerances on page 228. Because he fails to refer the residual aberrations back to the position of focus, he gets tolerances that are twice too large. He obtains the same expression that has been published before, but this has always been derived for a fixed-slit tester. Berry's tester is a moving-slit type. This problem is easily fixed, however. Just take the "demanding" tolerance as the true tolerance.

I also winced when I saw the label "¼-wave" applied to the graph on page 230. The Millies-Lacroix tolerances reflect errors in wavefront slope, not total wavefront deviation. My last complaint on the handling of the Millies-Lacroix method is that Berry doesn't use the flat graph with the parabola already taken out. For the mirrors I've figured, I found that using the flat graph makes interpretation much easier.

But don't misunderstand me. Mirror making is *not* the point of this book. Berry could have omitted this section entirely and the book would still be good. I have the distinct impression that he wrote the two chapters on optics grinding just to give the reader a taste and to archive some modern methods. He points out more complete references in his extensive appendices.

Building Your Own Telescope is an excellent guide to telescope assembly from a non-machine-shop viewpoint. Older telescope-making books describe Springfield mountings and fabulous metal casting and machining work but don't really address what the isolated individual without machine tools is truly capable of. This book describes telescope making for ordinary people. To beginners it will make a great difference in the probability of success.

The next time someone asks me for telescope plans, I won't stand there with my mouth hanging open. I'll hand over Berry's book. *Dick Suiter.*

The Halley Project:
A Mission In Our Solar System
Software for Commodore 64/128, Atari 800, and Apple computers
List price $44.95
Mindscape Software

The Halley Project is a slick computer game that shows a lot of polish. The Commodore and Atari versions are on opposite sides of a "flippy" disk; an Apple version will be released shortly. An audio cassette is also included that chooses you for the mission, a la *Mission Impossible.* The fiction continues with a sealed "dossier" package that contains detailed operating instructions and a handy reference card.

The disk has room to record thirty-two players' names and score times. I was glad to see that the software producers, while taking the usual precautions of copy-protecting the disk, did so without subjecting me to all the head-thrashing and banging I've been through with so many protected diskettes.

The basic task in this combined game and simulation is to pilot your spacecraft between Halley's Comet and various solar system destinations. You must complete each mission in turn before gaining access to more challenging ones, but you can re-try any previously completed mission to improve your score, which is recorded on the disk and screen.

The first destination is Earth. You navigate by switching back and forth between a visual cockpit view of the starfield and a "radar plot" of your relative position and distance within the solar system. Only the Sun (a yellow dot) and Comet Halley (a flashing dot) are identified in the radar view. It's up to you to be familiar enough with the orbits of the planets and their satellites to successfully find your way to each destination.

The planets, satellites, and Halley are in constant orbital motion and are shown pretty accurately to scale. Each start-up of the simulation finds them in different orbital positions. Around the screen are the names of the zodiacal constellations to aid you in visually navigating to your destination.

Switching to the cockpit view, you refer to a simple star map supplied in the dossier as you use the joystick to scan the starfield for the target constellation. You probably won't see your destination planet until you get reasonably close. As you move in, planetary motion and parallax set the planets off from the background starfield.

As you get closer to the target, a cockpit planet-finder identifies the object ahead and gives its range in kilometers. You have to time your approach carefully to avoid crashing into the planet or whizzing past it. Closer in, you see the light and dark sides of the planet and its satellites.

This game is really challenging: you have to know the relative orbital paths of the planets and their satellites to get *anywhere* with the simulation. The first mission, Earth, is a giveaway, but subsequent mission directives are much more challenging because they give you less specific information. For example, a directive might say "Head for any planet that doesn't have a satellite" or "Head for any satellite of Saturn having no atmosphere and a diameter less than 1,500 kilometers." You are told that this could be either Tethys or Dione, but the other destinations you have to figure out for yourself.

Since the time you take to accomplish a mission is part of your score, I found that I had to quit the game or put it on "pause" while I dashed off to consult an astronomy reference book. Once you know where you're going, you can continue without running up your time enormously. It would have been handy to have put a solar system database right on the disk that you could access if necessary, using a time penalty for each access to keep things fair.

Actually landing on a target planet isn't too difficult. Once you get closer than 100,000 kilometers, center one edge of the planet in your finder and slowly orbit until you receive the signal to land. By hitting "A" on the keyboard, you land automatically. You are treated to a view of the planet's surface and then instructed to return to Halley.

For a tougher gaming challenge, zoom in much closer and try to orbit without crashing. A crash adds a five-minute penalty to your time and repositions you a few thousand kilometers out for a re-try. (Would that the world really worked this way!) You may have to orbit the dark side of the planet or satellite to find the landing site. This becomes touchy at close range because the smaller planets and satellites are more difficult to land on without crashing.

Note to Commodore users: The software has a feature that lets you erase all the players' names and scores. When you set up each time, be careful to plug your joystick into port 2 as the manual states. I found out — the hard way, of course — that if you accidentally use port 1, pressing the fire button scrubs the names and scores record. Luckily, I had completed only two missions.

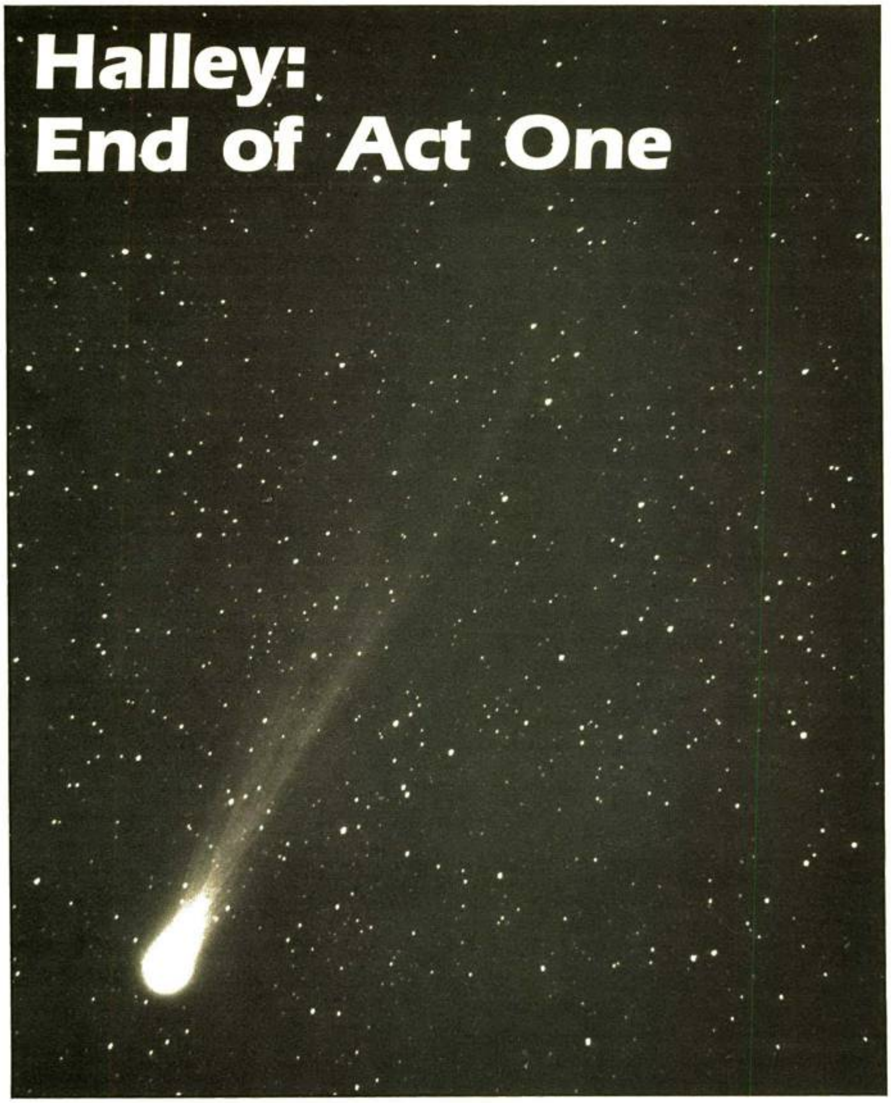
This is an enjoyable and educational simulation that is suitable for young teens and adults. Younger pilots can also have fun with it if given a bit of guidance and a reference book or two. I loaned *Project Halley* to some friends who had only a rudimentary knowledge of the solar system but who were experienced gamers. The navigation posed no problems and they had a great time, even though they had to research every destination.

Most of the graphics are adequate and seem to be correctly scaled. However, the appearance of the planets is crude at best. The manual states that this was the best they could do within the limitations of the equipment. Actually, using disk files, such as many other games and simulators do, would result in better graphics. On the other hand, I *did* like the speed and smoothness of not having to access the disk during play except to log my score between missions. *James Bailey.*

Space Travel: A History
Wernher von Braun, Frederick I. Ordway III, and Dave Dooling
308 pages, hardcover, $29.95
Harper & Row (1985)

A history of rocketry and space travel from the invention of gunpowder to the Space Shuttle, this work is an updated edition of an earlier work. This edition is illustrated with many photographs and line drawings.

Halley: End of Act One



Right: On January 10, astronomers Gene and Carolyn Shoemaker photographed Halley's Comet using the 18-inch Schmidt telescope on Palomar Mountain, California. This 7.5-minute exposure on Ektachrome 200 sheet film shows subtle, intricate details in the comet's long, slender gas tail. Photo courtesy Bobby Bus, Lowell Observatory. Above: Two nights before the Palomar photo was taken, Geoff Chester made this photo of Halley from Rixeyville, Virginia. He used a 5.5-inch f/3.64 Schmidt-Newtonian, hypersensitized Tech Pan film, and a 30-minute exposure.

By the end of January Halley's first act was over. The comet had become impossible to view, having sunk into the horizon during early evening while immersed in twilight in the southwestern sky. The buildup of excitement over observing Comet Halley, which had worked into a crescendo since last August when the comet became bright enough to observe with backyard telescopes, suddenly died. Halley would be invisible for a month — two weeks on either side of perihelion on February 9 — and backyard astronomers would have a chance to take a rest and hope for the best when Halley reappeared in late February's morning sky.

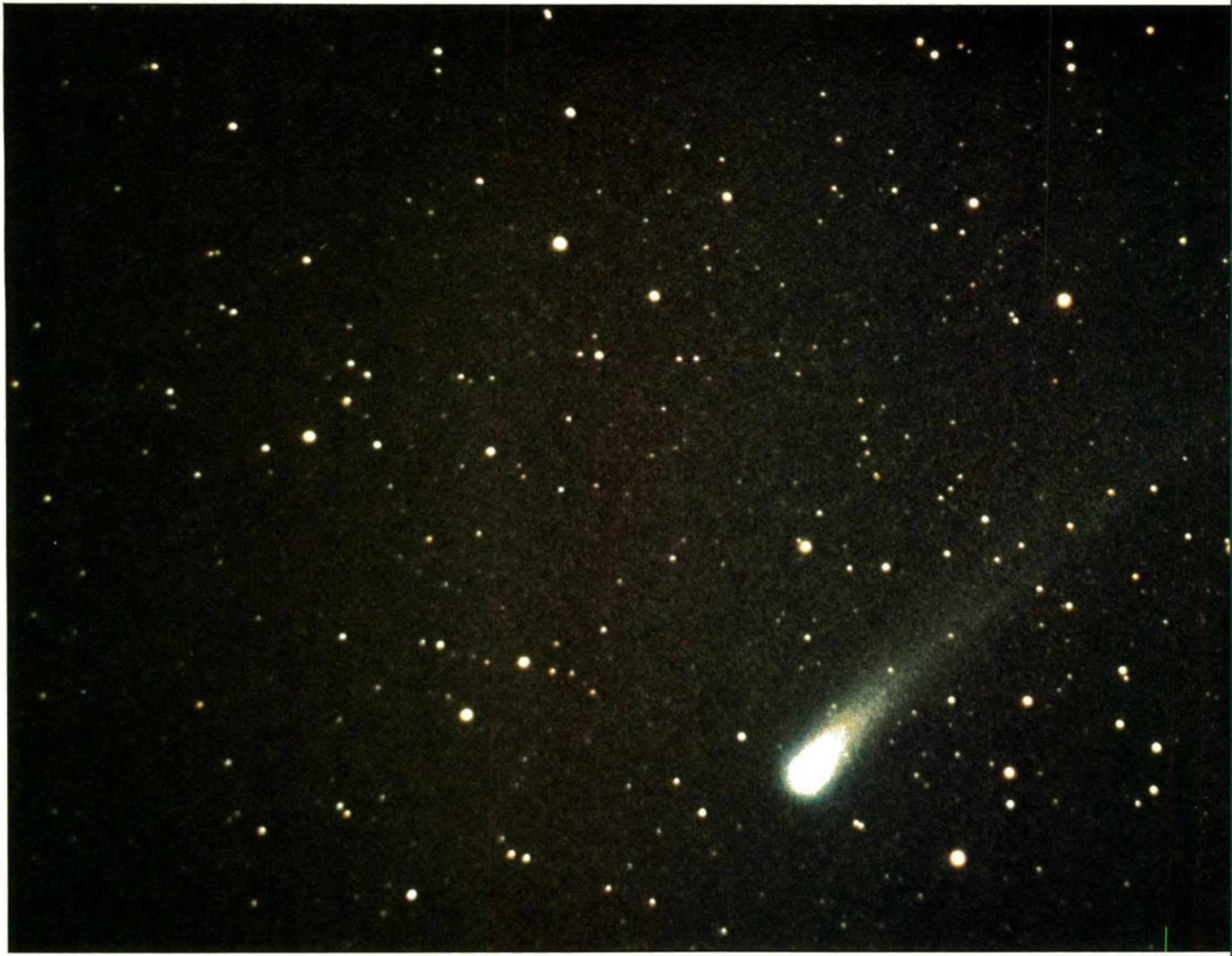
Halley in Late January

There were few observations of Halley made during the last half of January. The First Quarter Moon lit up the evening sky by January 17 and made finding the comet, which shone at about 4th magnitude and had a tail 3° long, difficult if not impossible. Some of the last observers to see Halley before perihelion were Richard Berry, Alan Hale, and Rick Shaffer, who observed the comet on the evening of January 27 about forty miles north of Los Angeles. Shaffer had a 19-inch Dobsonian telescope and 10x70 binoculars, and Hale had an 8-inch Newtonian. Berry had no telescope; he was temporarily in Los Angeles to cover the Voyager Uranus flyby.

After setting up the telescopes and dark adapting, the group "saw Halley at about the same altitude as Jupiter," said Berry. The bright star Beta Aquarii was nearby and made identifying the area easy. We kept observing Halley as it slowly set through thin cirrus clouds." Berry described the binocular view of Halley at that late date: "The 10x70 binoc's showed Halley as a fuzzy star with a faint tail extending perhaps as much as 15′ toward the zenith. Its total magnitude was a little less than Beta Aquarii, and it wasn't very exciting because the comet's subtle light appeared against a sky filled with bright twilight. Shaffer, Hale, and I never saw it under a really dark sky — it was too late for that. But it didn't matter; I figured this was my last chance to see the comet before perihelion. I'm glad to have spotted it so late." Several minutes later, Halley set behind a mountain.

On the same evening in Tucson, Arizona, David H. Levy went to the Tumamoc Observatory in hopes of imaging Halley one last time for the International Halley Watch. Levy had been routinely making photographs of Halley, specifically looking for jets emanating from the comet's nucleus with Tumamoc's 20-inch reflector and a sophisticated CCD camera. Doubting that the CCD imager would operate properly when the comet was in bright twilight, Levy opened the observatory anyway and tried to find Halley. After a few minutes' searching he did find it, first in the 6-inch finder-scope and then on the CCD video monitor. The telescope's field of view was small — some 8.5′ or one-seventh of a degree — and the comet would be setting quickly. Levy had to work fast. After a few minutes he recorded a large dust jet spurting out of Halley's nucleus and toyed with the contrast on the monitor — there wasn't much to be done about the bright sky. Then a peek through the finderscope showed a dark landscape fast approaching. Levy made one more exposure — a photograph showing Halley's nucleus about to set over the Tucson Mountains.

From Warsaw, New York, Elliott Hume wrote of his experiences with Comet Halley during January. "It has not been an easy task from this location, with both Buffalo and Rochester nearby," writes Hume. "*On January 9, I went to the* hilltop southwest of this village of 4,000 people and easily saw Halley in a dark sky using both naked-eyes and binoculars. I



believe I saw Halley naked-eye from my slightly light-polluted backyard on January 14, but the sky clouded over by the time I tried to confirm it with a telescope."

On January 21 Hume along with a group of school children and their parents spotted Halley's Comet using a 4.5-inch reflector and binoculars. Hume remarked: "On January 9 Halley had a larger perceptible diameter and seemed bright at about magnitude 4.5. On the 21st we were only a few days away from Full Moon, causing Halley to appear faint and small."

Most observers who had good weather during the last half of January had their final view of Halley around the 21st, and the comet's degenerating image certainly didn't inspire them to keep watching as conditions worsened. A small handful of observers saw Halley as late as Berry and Levy did; by the 28th of January, the thrill of trying to spot Halley in the evening sky had gone with the comet. Now observers' eyes turned toward February: when would Halley first be observed after passing behind the Sun?

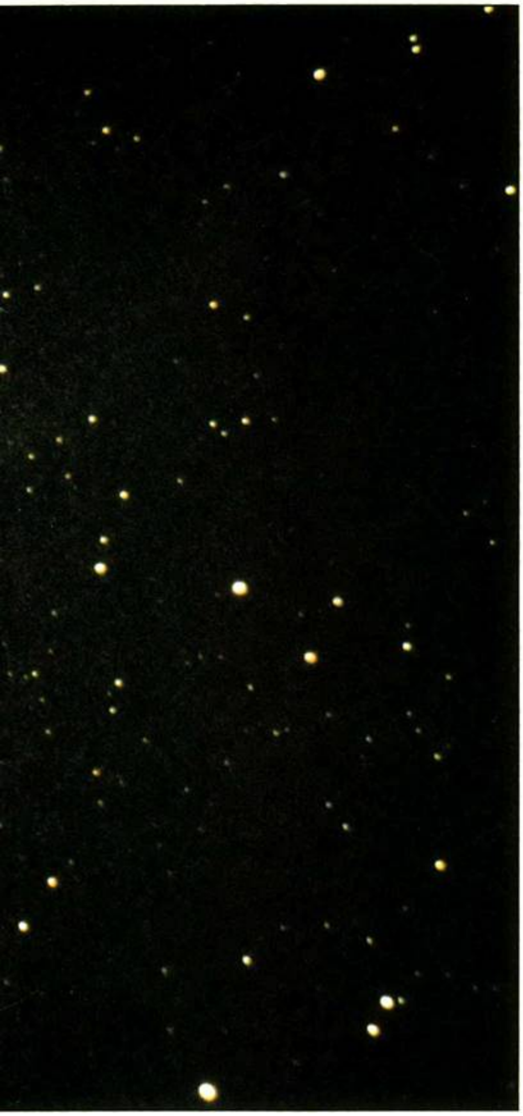
Halley in February

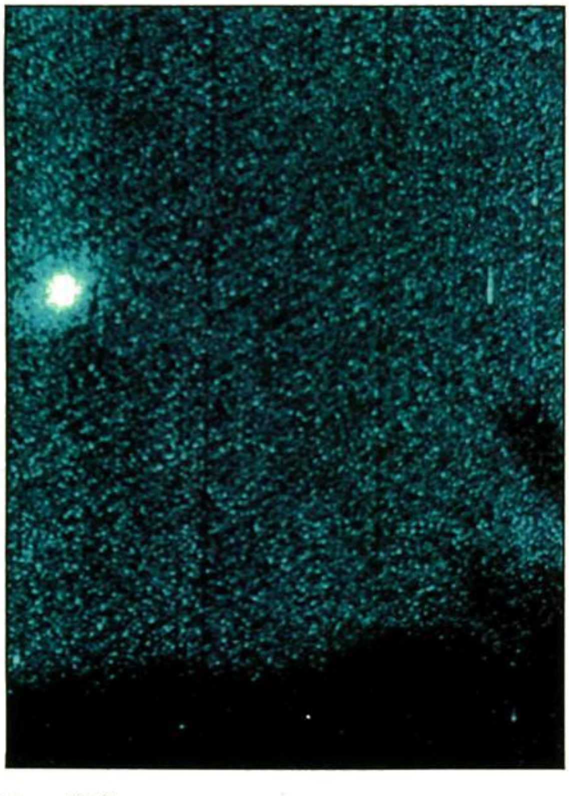
Astronomers at the European Southern Observatory in La Silla, Chile, spotted Halley's Comet on the morning of February 15, just six days after perihelion. Richard West (after whom Comet West is named) and the Belgian astronomer H. Debehogne observed Halley just above the eastern horizon in a brightly lit sky. They described the comet as about magnitude 3 and were happy to have recovered Halley on the "other side" of perihelion.

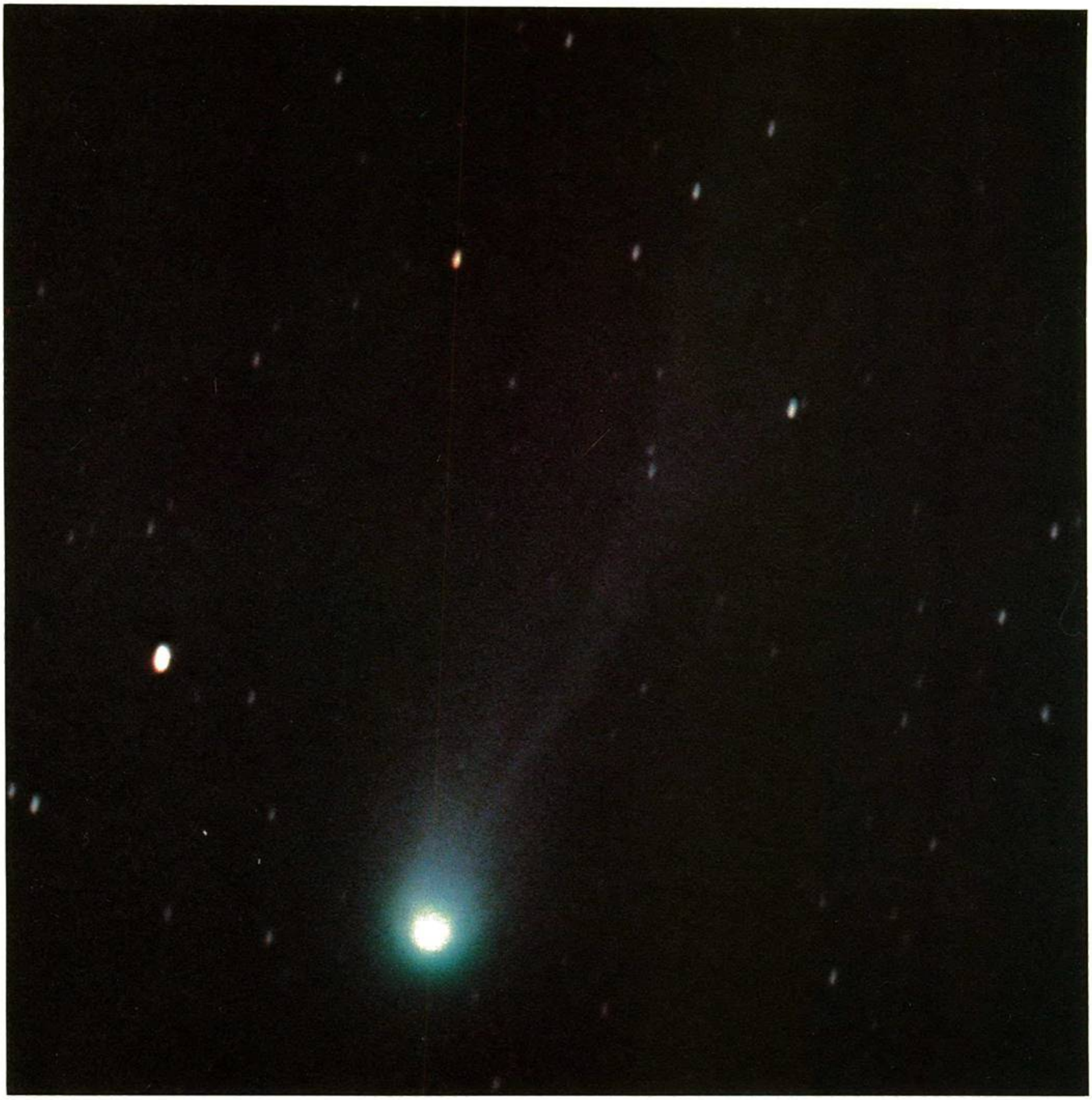
Stephen W. Bieda Jr. of Sierra Vista, Arizona, wrote of his recovery of Halley in the pre-dawn sky: "Yesterday morning and this morning, the 17th and 18th, I made my first sightings of Halley since losing it in the evening twilight last January 26. I found Halley quite easily with binoculars yesterday shortly before 6 a.m. It took only a few seconds to find the comet, despite the fact that it lay in deep twilight and was only a few degrees above the horizon. Last January I found Halley's telescopic appearance quite spectacular, and now it seems that the comet will try to duplicate its earlier show on a grander scale."

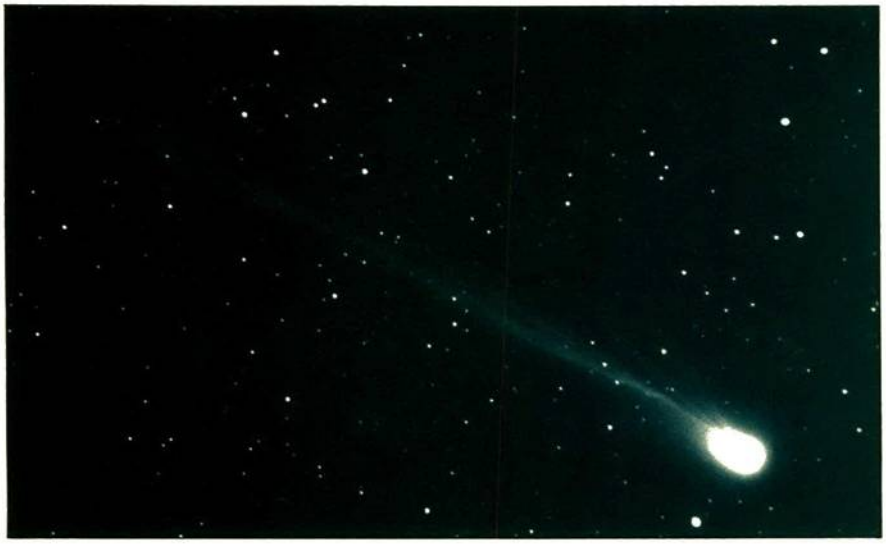
At press time, Halley's "spectacular show" in March and April is still an unknown quantity. It will certainly be

Above: On January 11, Hal Jandorf made this photo of the comet. Halley shone at around 4th magnitude and sported a bright tail stretching some 4°. Jandorf used a 5.5-inch f/3.64 Schmidt-Newtonian, 3M 1000 film, and a 10-minute exposure. Top right: Because Halley was drawing closer to conjunction in January, it was visible only briefly in January evening skies. Bruce Woidyla's photo shows a view that many backyard observers had as the comet sank into evening twilight. This photo was made on January 6 with a 200mm f/3.5 lens, Fujichrome 400 film, and a 5-minute exposure. Far right: By employing a 30° prism in front of the camera lens, Chris Schur made this spectrum of Halley's Comet on January 12 that shows the comet's light spread into characteristic wavelengths. The spectrum was made using a 400mm f/6.3 lens, 3M 1000 film, and a 25-minute exposure. Right: On January 27, Halley appeared as a bright nucleus some 36" across setting over a mountain near Tucson. Astronomers Stephen M. Larson and David H. Levy recorded this view using the 24-inch reflector at Tumamoc Observatory coupled with a CCD camera only seconds before the comet set. The view is one of the last images made before perihelion. Photo courtesy University of Arizona.









Above: Juergen Schneider photographed Comet Halley on January 10 to capture this view of the kinky, distorted gas tail. Left: This sharply defined image of Halley's detailed gas tail and fan-shaped dust tail was made on January 10 by Steven Wheatcraft in Coshocton, Ohio. He used a 5.5-inch f/3.64 Schmidt-Newtonian, hypered Tech Pan film, and a 13-minute exposure.

brighter than 3rd magnitude and should have a tail many degrees long, but comets are unpredictable creatures. In any event, ASTRONOMY will look forward to receiving observing reports, photographs, and sketches of the comet throughout the duration of its visit, and will continue publishing them in the pages of the magazine.

— *David J. Eicher*

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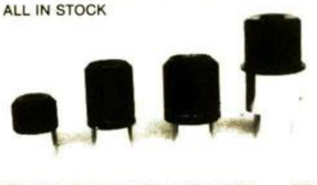
Specify Lens Size	**H-Alpha**	**(MV)**
46, 48, 49mm	**$35.00**	**$29.00**
52, 55, 58, 62mm	**$45.00**	**$35.00**
67, 72, 77mm	**$52.00**	**$45.00**
82mm	**$55.00**	

Hypered **2415** film, 36 exp ... **$9.95** ... **3/$27**

TELE VUE™ EYEPIECES USE THE BEST!!

ALL IN STOCK



7.4, 10.4, 13, 17, 21, 26mm Plossl, 50°	**$80**
1.8x or 2.5x Tele Vue Barlow Lens	**$80**
32mm Plossl, widest true field in 1¼"	**$95**
55mm 2" Plossl, widest possible field	**$175**
15mm Wide-Field, 1¼" eyepiece, 65°	**$110**
19mm Wide-Field, 1¼" eyepiece, 85°	**$125**
24mm Wide-Field, "superb", 65°	**$140**
32mm Wide-Field, 2" eyepiece, 65°	**$210**
40mm Wide-Field, "awesome", 65°	**$265**
4.8mm Nagler, 82° field	**$140**
7mm Nagler, 1¼" eyepiece, 82° field	**$175**
9mm Nagler, 82° field, "the best"	**$210**
11mm Nagler, 82° field, 1¼" or 2"	**$225**
13mm Nagler, 82° field, 1¼" or 2"	**$235**

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LUMICON Products catalogue $2.
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NEW! ENHANCED SILVER DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 3.1" enhanced silver diagonal mirrors & 2" star diagonal.
The new LUMICON diagonal mirrors have a special enhanced silver coating with a protective overcoating for long life. Visible reflectivity is 98-99% compared to 86-89% for standard aluminum coated mirrors. The extra 10-12% transmission is like adding an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32"	**$29.95**	1.52"	**$34.50**	1.83"	**$39.50**
2.14"	**$47.50**	2.60"	**$59.50**	3.10"	**$79.50**
4.25	**$129.50**				

ENHANCED SILVER STAR DIAGONAL

90° star diagonals with above enhanced silver mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

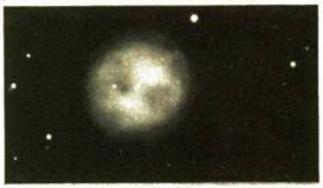
1¼" (1.32" mirror)	**$79.50**
2" (1.83" mirror)(see photo above)	**$129.50**

LUMICON FILTERS STOP LIGHT POLLUTION

UHC Filter™

ULTRA HIGH CONTRAST

The **LUMICON UHC FILTER** is specially designed for visual astronomy in areas of severe light pollution or for viewing very faint nebulae at any location. **UHC** stands for **U**ltra **H**igh **C**ontrast and this filter is guaranteed to yield a higher visual contrast on planetary and emission nebulae than any other filter at any price. 24nm visible bandpass, 482-506nm.



"I CAN SEE THE OWL NEBULA!"
Tom Kramer saw the Owl Nebula, M-97, for the first time using a LUMICON UHC Filter. He stated, *"I had never seen M-97. . . I attached the UHC Filter and tried again. M-97 was right there. I could not believe it! The UHC Filter should be standard equipment."* **Tom Kramer, Sayville, NY**

For optimum astronomy, use either the **LUMICON DEEP-SKY Filter** or the **LUMICON UHC Filter**

DEEP-SKY FILTER™

The **LUMICON DEEP-SKY FILTER** improves your view of **all** deep-sky objects including galaxies and comets. It removes natural and man-made light pollution and yields 3-6x contrast gain for nebulae and 1-3x contrast gain for clusters and galaxies. It is ideal for **both** visual use and B&W or color photography. This gentle filter yields the most natural view of any LPR filter available today. 90nm visible bandpass. 442-532nm. H-Alpha 656nm transmission = 80-95%.

	Standard	**Premium***
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces		**$79.50**
48mm LUMICON DEEP-SKY Filter (1.75" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS		**$119.50**
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	**$99.50**	**$119.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)		**$299.50**
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	**$79.50**	**$99.50**
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	**$159.50**	**$199.50**
Set of Both 1¼" **DEEP-SKY** and **UHC Filters** (Save 11%)		**$159.50**
1¼" H-BETA Line Filter 9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae)		**$89.50**
48mm "Horsehead Nebula" H-BETA Line Filter		**$189.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae. 11nm bandpass at 496nm and 501nm 0-III lines	**1¼" $99.50,**	**48mm $199.50**
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm		**$6.95**
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece		**$16.00**
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece		**$20.00**

**Premium filters are selected best of the lot and typically have 5-10% higher transmission. Not always available. Include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

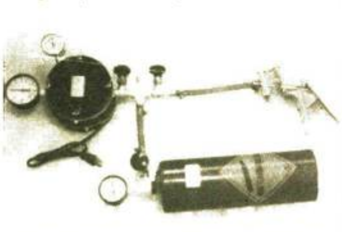
FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15X film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

†Patent Pending

MODEL 100 HYPER-KIT for 35mm film, rolled-up. *Takes longer*, but it easy to use. Not recommended for 2415 ... **$225.00**

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds ... **$295.00**



MODEL 600 HYPER-KIT [See Photo] Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates ... **$350.00**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller ... **$595.00**

Temperature controller for any HYPER-KIT ... **$59.50**

Electric Vacuum Pump ... **$280.00**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X eaiser guide-star selection, use 48mm filters, 360° camera rotation, large prisms fo bright guide-starts. *Specify Camera and Telescope type.*
U.S. Patent # 4,448,500

NEWTONIAN EASY-GUIDER™

Full aperture. Installs in secs. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$169.50**
3X Relay Diagonal (see photo)	**$79.50**
Illuminated reticle eyepiece system	**$79.50**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Dynamax-8. Includes 50mm achromatic lens for f/5.8 operation-3X shorter exposures! **Superb rich field viewing, too!**
CASSEGRAIN EASY-GUIDER ... **$225.00**

GIANT EASY-GUIDER™

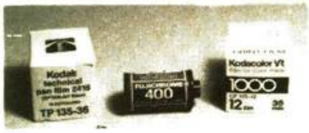
For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER	**$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20)	**add $99.95**
Hasselblad adapter	**$195.00**

WHAT DO YOU NEED?

1. **Illuminated reticle eyepiece** . . . $79.50
Lumicon 12mm eyepiece system has adjustible L.E.D. illumiation, dual crosslines, battery pack.
2. Cable release for long exposures **$9.95**

3. **LUMICON Quartz Drive Corrector . . $219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.
Declination motor (state telescope) . . $60



HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography.

Film Type (35mm unless marked)	**Esposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	**$9.95**
VR200, fine grain color negs	12	**$9.95**
3M 1000, fastest slide film	20	**$12.95**
SR1600, fastest of all, color negs	24	**$12.95**
5072, color slides from negs	36	**$6.95**
D-19 B&W Developer	1 gal.	**$6.95**

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Meade® TELESCOPES AT LUMICON

MEADE 2080/LX3 .... $1695

2080/LX3 System w/wedge & tripod ($2800 list)	**$1695**
2080/LX2 System w/wedge & tripod ($2450 list)	**$1495**
Multi-coated silvered optics, boost trans. 18%	**add $149**
#36 dual-axis drive corrector control box ($150 list)	**FREE**
#38 declination motor & clutch ($150 list)	**FREE**
Dew shield and accessory tray	**add $89**

2080/LX3
$1695
IN STOCK!
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Dual axis
drive system
($300 value)
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NEW! Quartz Drive Meade 2080/LX3

The Meade 2080/LX3 with built-in quartz electronic drive system is positively the highest performance 8" Schmidt-Cassegrain telescope system available today.

- Certified diffraction-limited optical system
- Built-in quartz microelectronic sidereal drive system
- 8x50mm right-angle illuminated Polar viewfinder
- Multi-coated prism star diagonal (99% transmission)
- 25 ft. cord for field operation from a 12V car battery
- 25 ft. cord w/ converter for 110VAC 50/60 Hz operation
- Output jacks for illum. reticle eyepiece and map light
- Equatorial wedge with compass, bubble level, micro metric azimuth control
- Piggyback camera mount for effortless wide-field photography (**Best to photograph Comet Halley!**)
- Audio cassette explains features, set-up, visual & photographic applications

FEATURES OF BOTH 2080/LX2 & 2080/LX3

- Lifetime warranty on telescope, wedge, tripod
- 8"f/10 Schmidt-Cassegrain optics, F = 2000mm
- 20mm Research-Grade Erfle 1¼" eyepiece (100X)
- 7mm Research-Grade Orthoscopic eyepiece (286X)
- High transmission coatings on the front corrector lens
- Ultraprecision 6" LX worm gear motor drive
- Oversize 8.25" primary mirror benefits photography
- Convenient fork mount with slow motion controls
- Best overall mechanical stability of any 8" Cassegrain
- Large right ascension & declination setting circles
- Padded carrying case
- Eyepiece rack
- Lattitude scale and no-tool knob set
- Adjustable height heavy duty tripod with eyepiece rack
- Dew shield & accessory tray, optional **add $88**
- Star map & finder cards for Messier objects
- Red astronomer's night flashlight
- **Optional:** Multi-coated/silvered optics boost transmission 18%, **add $149**

2120/LX3 10" System $2695

The 10" Meade 2120/LX3 collects 56% more light than an 8" telescope for significantly improved viewing and astrophotography. It has all the features of the 2080/LX3 (see above.)

Meade 2120/LX3 w/wedge & tripod ($4500 list)	**$2695**
Multi-coated silvered optics boosts transmission 18%. Highly recommended!	**$195**
#710 dew shield (10") Essential!	**$98**
#36 dual-axis drive corrector control box	**$99**
#38 declination motor and clutch	**$99**
LUMICON Giant EASY-GUIDER/Rich-Field viewer for f/4-f/10 operation (state camera)	**$395**

4" MEADE 2045 w/ table tripod ... $650

IN STOCK!
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Meade Model 2045 — Advanced engineering and superb optical performance in a beautiful ultraportable system.

FEATURES OF THIS TELESCOPE

- 4"f/10 Schmidt-Cassegrain optics, F = 1000mm
- High transmission coatings on front corrector lens
- Table tripod for easy polar alignment
- 5X24 straight-thru finderscope
- 1¼" right-angle star diagonal
- 1¼" 25mm (40x) and 9mm (111x) eyepieces
- Sturdy fork mount with setting circles
- Manual slow motion controls
- Star map & red astronomer's flashlight

HIGHLY RECOMMENDED OPTIONS

Model 43 drive corrector uses 12VDC ($120 list) **$96**
See Meade 2080/LX2 options
Wedge & field tripod as for 2080/LX2 ($470 list) **$298**
Dew shield .... **$45** Solar Filter **$126**

80mm REFRACTOR $495

Model 310 ($700 list) **$495**

Excellent for both terrestrial & astronomical viewing 80mm (3.1") f/11 refracting telescope includes 1¼" focuser, 6x30mm finderscope, 36X and 100X 1¼" eyepieces, adjustable height tripod with accessory tray, and alt-azimuth mount with slow motion controls.

Model 320 ($900 list) **$630**

Identical to 310, but has equatorial mount with setting circles.

Quartz motor drive	**$169**
Basic camera adapter	**$32**
Easy-Guider (state camera)	**$149**

OPTIONS BOOST PERFORMANCE

LUMICON UHC Filter for nebulae. Standard 1¼" **$79**
Prem 1¼", **$99;** Std 48mm, **$149.50;** Prem 48mm, **$199.50**
LUMICON Deep-Sky Filter, 1¼" Premium **$79**
48mm Prem Deep-Sky ...... **$119.50, $99.95** w/Easy-Guider
Adapter for viewing w/1¼" eyepiece **$20**
Dust covers. Keep optics clean. For 6" **$16/pair**
8" .... **$20/pair;** 10" .... **$18;** 16" **$24**
LUMICON Rich-Field Viewer (2080) **$140**
LUMICON Newtonian Easy-Guider, 1¼" or 2" **$169**
#122 2X Barlow ($60 list) **$48**
Dual-axis drive corr. and elec. dec. for 2080/LX2 .. **$298**
for model 628, 826, DS-10 .... **$340** for DS-16 .... **$440**
Tele Vue 32mm Plossl 1¼" eyepiece **$88**
LUMICON Cassegrain EASY-GUIDER for 2080/LX2 & LX/3 (state camera) **$225**
Illuminated reticle eyepiece & battery pack **$79.50**

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All telescopes shipped F.O.B. Livermore

8" f/6 NEWTONIAN $995

BEST VALUE!

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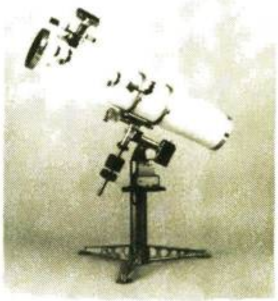
PRICES!



Model 826, 8" f/6 Telescope w/accessories

Model 628, 6" f/8 with motor drive ($1220 list)	**$750**
Model 628C, 628 w/2" focuser, 8x50mm finder ($1350	**$850**
Model 826C, 8" f/6 with motor drive, #680 2" focuser and 8x50mm finderscope ($1530 list)	**$995**

—Collects 78% more light than a 6" telescope.

These Meade Deluxe Series reflecting Telescopes have superb image quality at low or high power. They include an equatorial mount with motor drive, pier, legs, setting circles, 1¼" rack & pinion focuser, 6x30mm finderscope, 25mm (48x) and 9mm (135x) 1¼" eyepieces, altitude and azimuth fine adjustments for polar alighment.

#43 drive corrector uses 12VDC ($120 list)	**$96**
#47M Dual-axis drive corrector & elec. dec.	**$340**
1¼" or 2" EASY-GUIDER (state camera)	**$169**

6" f/5 NEWTONIAN $695

IN STOCK!

LAST
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PRICES!

Models 6600 (6" f/5) & **8800** (8" f/4.5) telescopes

Model 6600, 6" f/5 Newtonian telescopes ($1100 list) .. **$695**
—Best performance & value; bright, wide views.
Model 8800, 8" f/4.5 Newtonian Telescopes ($1400) ... **$895**
—Collects 78% more light than a 6" telescope.

These meade Professional Series reflecting telescopes yield superb rich-field viewing w/bright images. They include an equatorial mount w/adjustable tripod, setting circles, slow motion controls, 6x30mm view-finder, 1¼" focuser, 25mm & 9mm 1¼" eyepieces & accessory tray.

#784 Quartz motor & quartz drive corrector	**$169**
Basic camera adapter (for moon & planets)	**$32**
1¼" LUMICON Easy-Guider (state camera)	**$169**

16" f/4.5 NEWTONIAN $1995

LAST
CHANCE
AT 1985
PRICES!

Meade DS-16A with Accessories

The DS Series of 10" and 16" reflecting telescopes are ideal for deep-sky viewing and photography.

DS-10A, 10" f/4.5 with motor drive ($150 list) **$995**
—Gathers 56% more light than an 8" telescope
DS-16A, 16" f/4.5 with motor drive ($3050 list) **$1995**
Sealmaster ball bearings, highly recommended ... **add $229**
—Gathers 400% more light than an 8" telescope

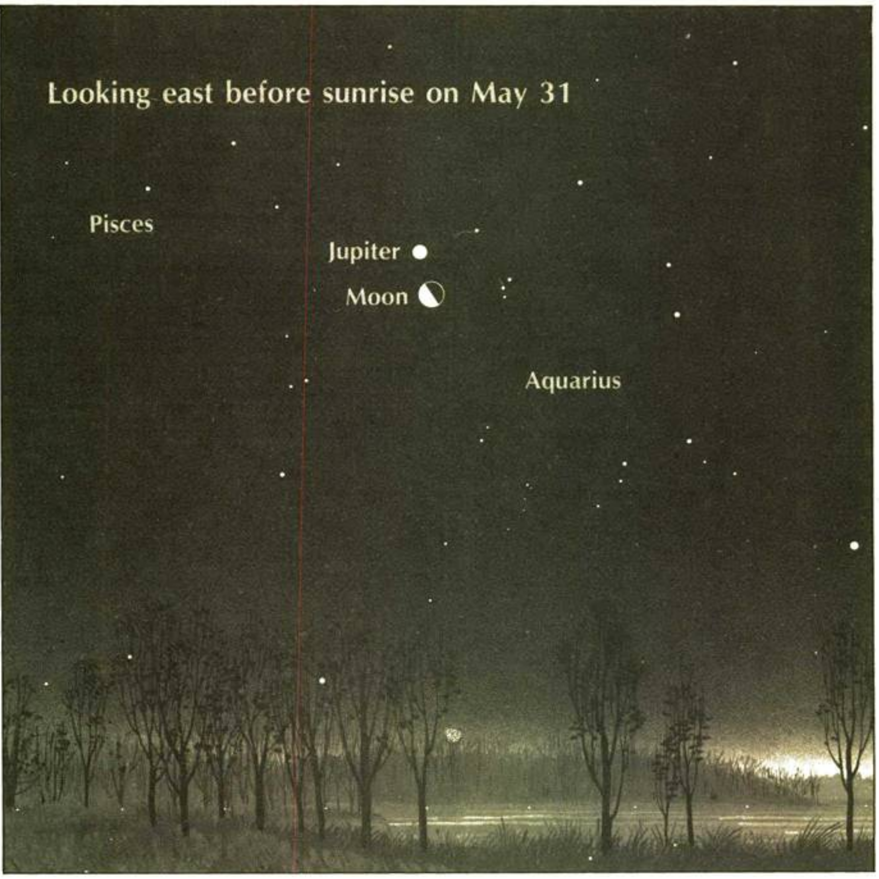
Both the DS-10A and DS-16A telescopes include an equatorial mount, #680 2" focuser, motor drive, setting circles and 25mm 1¼" eyepieces.

6x30mm finderscopes with brackets ($46 list)	**$39**
8x50mm finderscope with brackets ($114 list)	**$89**

Eye on the Sky

Saturn Reaches Opposition

by Robert Burnham



When this photograph was made on January 12, Halley's Comet was visible as a 4th-magnitude smudge in the southwestern evening sky. Two weeks later, it had moved closer to perihelion and was invisible. Along the horizon in this photo are a two-day-old Moon and Jupiter. Photo by Lawrence G. Boyer using a 50mm f/1.8 lens and a 2-minute exposure on Fujichrome 400 film.

The Wanderers

This month a bright "evening star" — the planet **Venus** — is visible above the western horizon after sunset. It shines at magnitude −4 but is so low on the horizon that from the typical backyard, trees, houses, and streetlights will probably block your view. So get a flashlight and cover its lens with grocery-bag paper or red cellophane, grab your ASTRONOMY with its Star Dome map (see center spread), and find a local ball field or schoolyard that affords a clear view to the west.

Venus is moving eastward along the "path of the planets," the ecliptic. During May, it travels among the stars of Taurus and Gemini, though these constellations (along with bright Orion to the south) are either obscured by horizon haze or have already set. Venus itself sets about two hours after the Sun.

When Venus finally disappears behind the horizon, **Saturn** will be rising into view in the southeast. Around 9 p.m. EDT on May 27, Saturn is at opposition to the Sun, meaning that it is 180° opposite the Sun from our vantage point. All night long Saturn will traverse the southern half of the sky, rising in the evening as the Sun sets and setting in the morning as the Sun rises. The planet is a creamy white object of zero magnitude lying some 7° north of the 0.9 magnitude star Antares (Alpha [α] Scorpii), whose ruddier color sets it apart from Saturn.

The next naked-eye planet to rise is **Mars**. By 1 or 2 a.m. it is visible over the trees and houses in the southeast as an orangy dot of light at magnitude −0.9. Mars is in Sagittarius but far outshines the Archer's brightest stars. Can you discern a slight change in Mars' brightness during the month?

Next in line along the ecliptic from Mars is **Jupiter**, which rises about two hours after the Red Planet. Jupiter rises earlier each night as autumn approaches, when it is visible in the early evening sky. Since this celestial landscape holds few bright stars, Jupiter's −2.2-magnitude white luminance shines especially brilliantly. Last year Jupiter was in Capricornus; this year it is in Aquarius, a constellation whose brightest star is a 2.9-magnitude object — over 100 times dimmer than the "king of planets."

One more naked-eye planet remains: **Mercury**. Unfortunately, Mercury lies too close to the Sun to be seen this month. On May 22 (in EDT), the planet passes behind the Sun. By the middle of June, however, it will appear in the evening sky.

Some time early in May, **Halley's Comet** will slip below naked-eye visibility. But the comet will be easily observed all month by anyone with even modest-sized binoculars. Halley is swinging northwestward through the constellations Crater and Hydra, where it passes near 4.1 magnitude Alpha (α) Crateris on April 30 and May 1, and 3.1 magnitude Nu (ν) Hydrae on May 3 and 4. (Nu Hya is identified on the Star Dome map). For detailed coverage of Halley's path during May and June, see "Following Halley Out," page 90.

The Starry Sky

The dome of stars that curves overhead on May evenings lacks the bright stellar landmarks of three months ago — and those of three months hence. Yet the constellations of late spring are simple to learn because their patterns are clear and large. During the first half of May — this month's "dark of the Moon" — take a late evening drive a dozen miles or so into the country. Stop along a back road (preferably near an open field), give your eyes ten minutes to adjust to the dark, and look overhead.

The foremost spring group is the Big Dipper, which now lies high in the north swinging over the pole and down toward the northwestern horizon. Its seven stars (eight if you include tiny Alcor next to Mizar) are known to nearly everyone. Actually, they form part of a much larger figure called **Ursa Major**, the Great Bear. Sadly, Ursa Major begins and ends with the Dipper for most people because the rest of the Bear's stars are invisible from light-polluted cities.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

May Night Sky

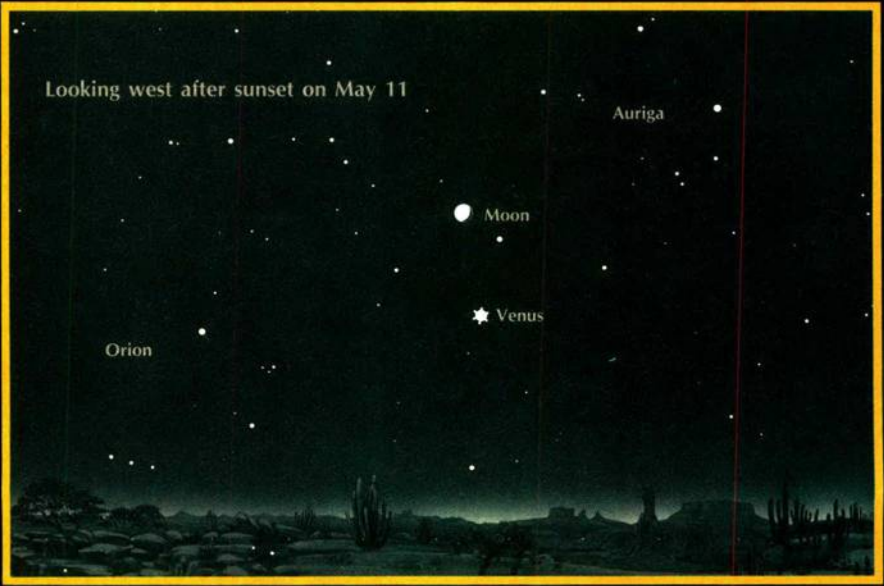
New Moon
May 8
6:10 p.m. EDT

First Quarter
May 16
9:00 p.m. EDT

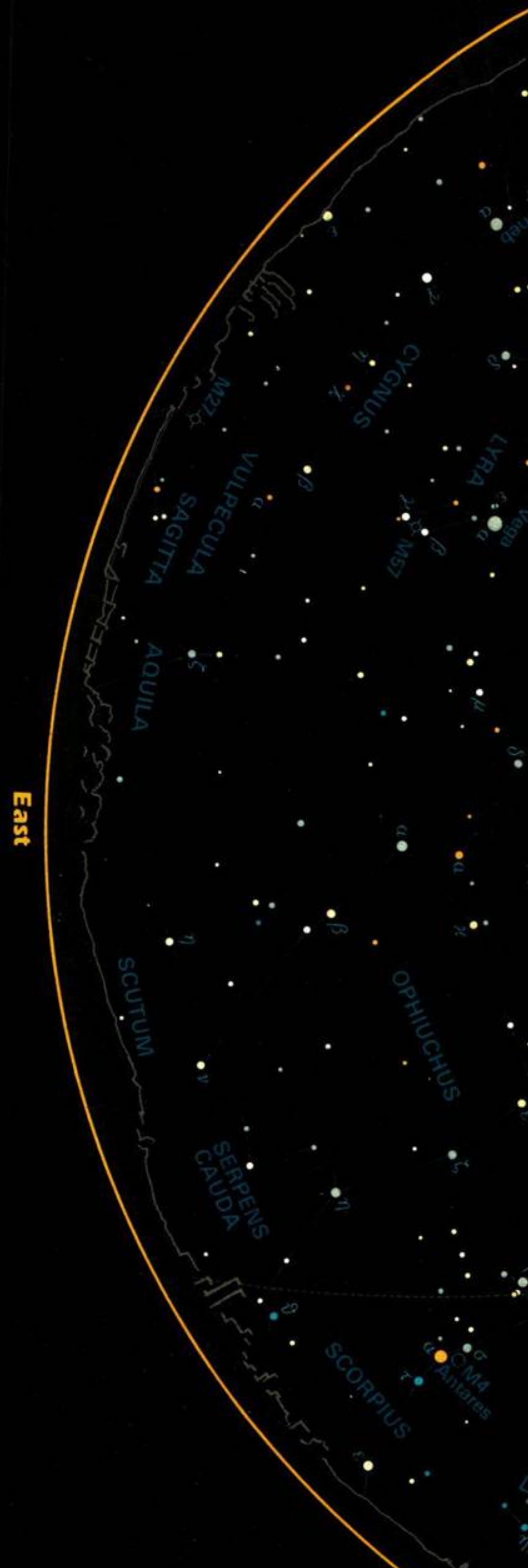
Full Moon
May 23
4:45 p.m. EDT

Last Quarter
May 30
8:55 a.m. EDT

3rd	A waning crescent Moon passes 3° south of Jupiter in the pre-dawn sky.
4th	The Halley-derived Eta (η) Aquarid meteor shower reaches peak activity today; look for about 20 meteors an hour coming from the Water Jar asterism in Aquarius between midnight and dawn.
8th	New Moon is at 6:10 p.m. EDT.
10th	The Moon is farthest from Earth at 6:40 p.m. EDT: 252,481 miles.
11th	Venus lies 3° south of the Moon in the evening sky.
16th	First Quarter Moon occurs at 9:00 p.m. EDT.
19th	Venus is at its closest to the Sun.
22nd	Mercury is in superior conjunction with the Sun (in EDT); it switches from the morning to the evening sky where it will become visible next month.
23rd	The Moon is Full at 4:45 p.m. EDT and closest to Earth at 11:01 p.m. EDT: 221,890 miles.
24th	The bright double star Antares in Scorpius is occulted by the Moon as seen from central Canada and the upper midwestern United States (see Backyard Astronomer for details).
25th	Mercury is at its closest to the Sun.
27th	In the pre-dawn sky, the Moon passes 3° south of Mars. Saturn reaches opposition to the Sun (in EDT). The planet lies on the border between Scorpius and Ophiuchus and is visible all night long.
30th	Last Quarter Moon occurs at 8:55 a.m. EDT. Minor planet Juno is at opposition.

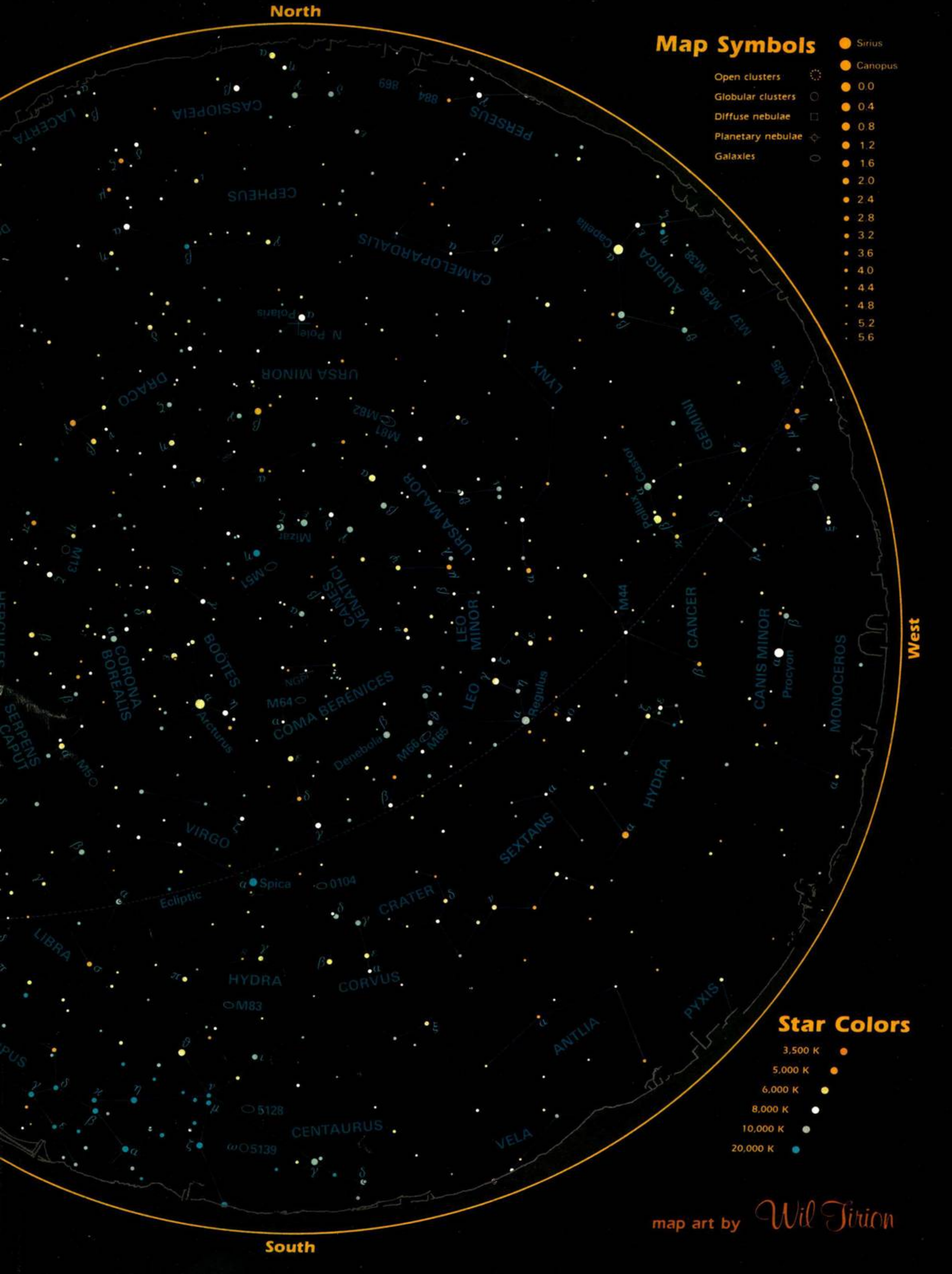


Looking west after sunset on May 11



The Star Dome shows how the sky looks at:

11:30 p.m. on May 1
10:30 p.m. on May 15
9:30 p.m. on May 31


North
South
West
Map Symbols
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies
Sirius
Canopus
0.0
0.4
0.8
1.2
1.6
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DRACO
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M82
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Castor
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M83
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PUS
5128
CENTAURUS
5139
VELA

map art by Wil Tirion

Top left: A waxing Moon and Mercury loom over a horizon reddened by volcanic ash in this January 1983 photograph of the morning sky. Photo by Johnny Autery using a 135mm f/2.8 lens, a 4-second exposure and Kodachrome 64 film. Bottom left: Noctilucent clouds illuminate the sky over Helsinki, Finland in this photograph made with a 50mm f/1.4 lens, a 1-second exposure, and 200 ISO film. Photo by David H. Frydman.

The two stars at the western end of the Dipper's bowl (α and β on the map) are called the Pointers since a line between them extended downward about five times their separation will reach Polaris, the Pole Star, in faint **Ursa Minor** the Lesser Bear. Ursa Minor is also called the Little Dipper, and Polaris marks the end of its handle.

Return to the Big Dipper and extend the arcing path of its handle outward. Your eye will encounter zero-magnitude Arcturus in **Bootes** the Herdsman. Bootes, a constellation generally resembling a skinny kite, was also known in Greek legend as the "Bear Driver" — an appropriate name since he perpetually chases both of the Ursae, Major and Minor, across the sky. The name Arcturus itself is derived from the Greek word for bear.

Between Arcturus and the southern horizon lies 1.0-magnitude Spica, the brightest star in **Virgo** the Virgin. Just above Virgo a dim sprinkle of stars indicates **Coma Berenices**, Berenice's Hair (see Skylore). Scanning Coma and Virgo with even a small telescope will reveal dozens of galaxies. These are members of the nearest cluster of galaxies to our own Local Group, of which the Milky Way Galaxy is a part.

After you "arc to Arcturus and speed on to Spica" (as the old mnemonic says), look to the lower right of Spica for a compact arrangement of five or six stars. This is **Corvus** the Crow, a constellation that dates back to ancient Greek times. To the right of Corvus lies **Crater** the Cup, an ancient group that represents the goblet of Apollo. From the way Crater tips, it looks as if someone is pouring wine on the Crow's tail.

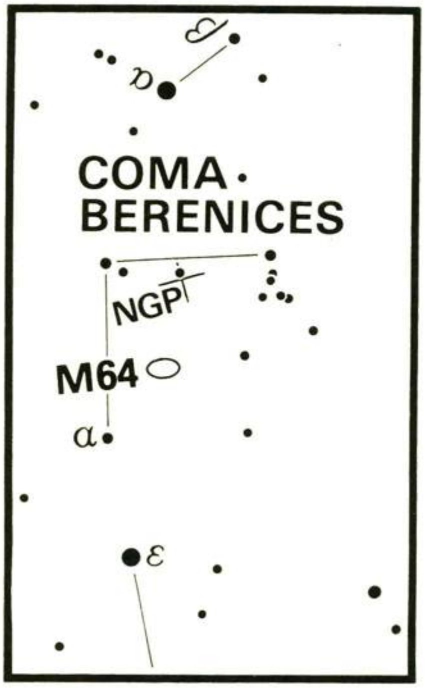
Between Corvus and the horizon lie the northern extremities of **Centaurus** the Centaur. Centaurus doesn't look like much from northern latitudes, but viewers in southern states can easily spy its great globular cluster Omega (ω) Centauri, a 4th-magnitude fuzzy glow; binoculars reveal a ghostly patch that marks NGC-5128, the enigmatic galaxy/radio source also known as Centaurus A.

Now crane your neck to locate the Big Dipper again. To the southeast of the Dipper's bowl lies diminutive **Leo Minor** the Lesser Lion; beyond that lies **Leo** himself with the bright "heart star" Regulus. Leo's forequarters are shown by Regulus, Eta (η), Gamma (γ), Zeta (ζ), and Epsilon (ε), which form a backwards "?" called the Sickle. Leo's tail and hindquarters are marked by Denebola, Delta (δ), and Theta (θ).

If you trace the ecliptic (marked by Regulus and Spica) eastward, you pass dim **Libra** the Scales and meet **Scorpius** the Scorpion very low on the eastern horizon. This year, Scorpius has a "guest" — Saturn — a frequent occurrence for any constellation along the ecliptic. In the center of the Scorpion lies 1st-magnitude Antares, a ruddy orange star whose name means "the rival of Mars." Right now the Scorpion is hard to see since it hasn't risen very far, but by next month it will be more prominent.

Skylore

When you first look between Denebola and Arcturus, if you notice anything at all it will be how dim and unprepossessing this piece of sky is. Yet this apparently barren region is attached to an amusing legend concerning a fast-talking astronomer/astrologer and an irate king and queen.



The king was Ptolemy III, surnamed Euergetes, and the queen was Berenice, his sister-wife. The occasion (in the 3rd century B.C.) was one of those never-ending Egyptian wars against the Assyrians.

As was the custom, Ptolemy had gone off to direct the fight personally and Berenice, whose name in Greek means "victory-bearing," was worried about his safe return. She asked Conon, the court astronomer, what she could do to ensure that the king would come back unscathed. After duly consulting the sky, ancient texts, and probably not a few animal entrails, Conon suggested Berenice make a solemn vow that should Ptolemy return unharmed, she would cut off her amber-colored mane of hair (of which she was greatly proud) and present it to the goddess of beauty, Aphrodite.

Two long years passed. Finally, in the spring of the year, a dusty and sweaty but triumphant Ptolemy returned to Egypt with his army and their spoils. Now it was time for Berenice to live up to her side of the deal.

Whether she did it delightedly or resignedly the legend doesn't say. In any case, the queen was as good as her word and the temple of Asinoe Aphrodite at Zephyrium was graced that day with her long golden locks.

Thus the curtain falls, so to speak, on a splendidly barbaric scene: the grateful (if close-shorn) queen, the touched and pleased king, the chanting priests, and the light from dozens of oil lamps glistening softly off the yellow pile of hair on the Altar of Aphrodite. (We can almost hear how Verdi would have scored the scene.)

But dawn the next morning brought a rude shock. The offering was gone, vanished without a trace.

When she learned of it, the queen was extremely angry. The king, too, shared in the outrage. "Where's our astronomer?" they shouted. "We demand an explanation!" Conon, it seems safe to say, was in very hot water — figuratively for the moment, but soon perhaps also literally.

In those times, however, no royal astrologer lasted long if he didn't possess nimble wits and a gracious tongue. Somehow Conon calmed down the royal pair and stalled them until evening. Then, as the cool dusk deepened into night, Conon invited them out onto the observing terrace of the palace. He pointed to a patch of sky between Leo and Bootes. The king and queen looked up and in the black vault studded with stars they beheld a tiny glitter of twinkling lights.

"There," Conon said, "is your offering, raised to heaven by the goddess herself."

Mythology aside, Coma Berenices didn't become a "real" constellation until the year 1602 when the famous Danish astronomer Tycho Brahe listed it as such in his catalogue of stars. Since Tycho's time, Coma has taken on new importance: to modern astronomers, this memorial to a faithful queen's love contains the north pole of the Milky Way Galaxy, one of the nearest clusters of stars, and one of the closest clusters of galaxies. In fact, much of today's cosmological research builds upon observations of the great cluster of galaxies in Coma and Virgo.

And the wily Conon? He has his memorial, too, though you won't find it among the stars. Some night around Last Quarter Moon, look with a telescope and medium magnification at the lunar Apennine mountains. Near Mt. Hadley is a crater 20 miles across, which stands as a monument to this clever astronomer — and to quick thinking under pressure.

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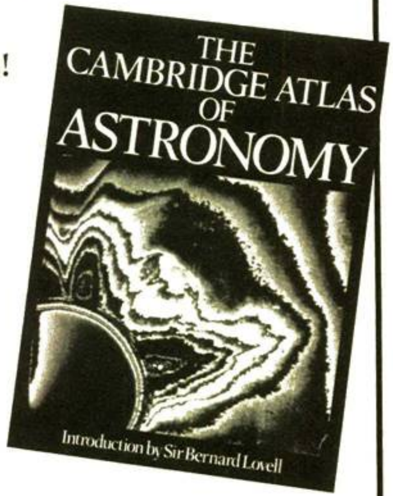
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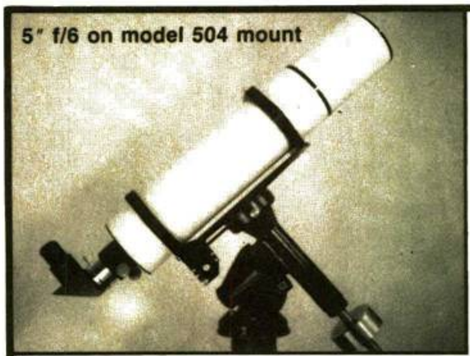

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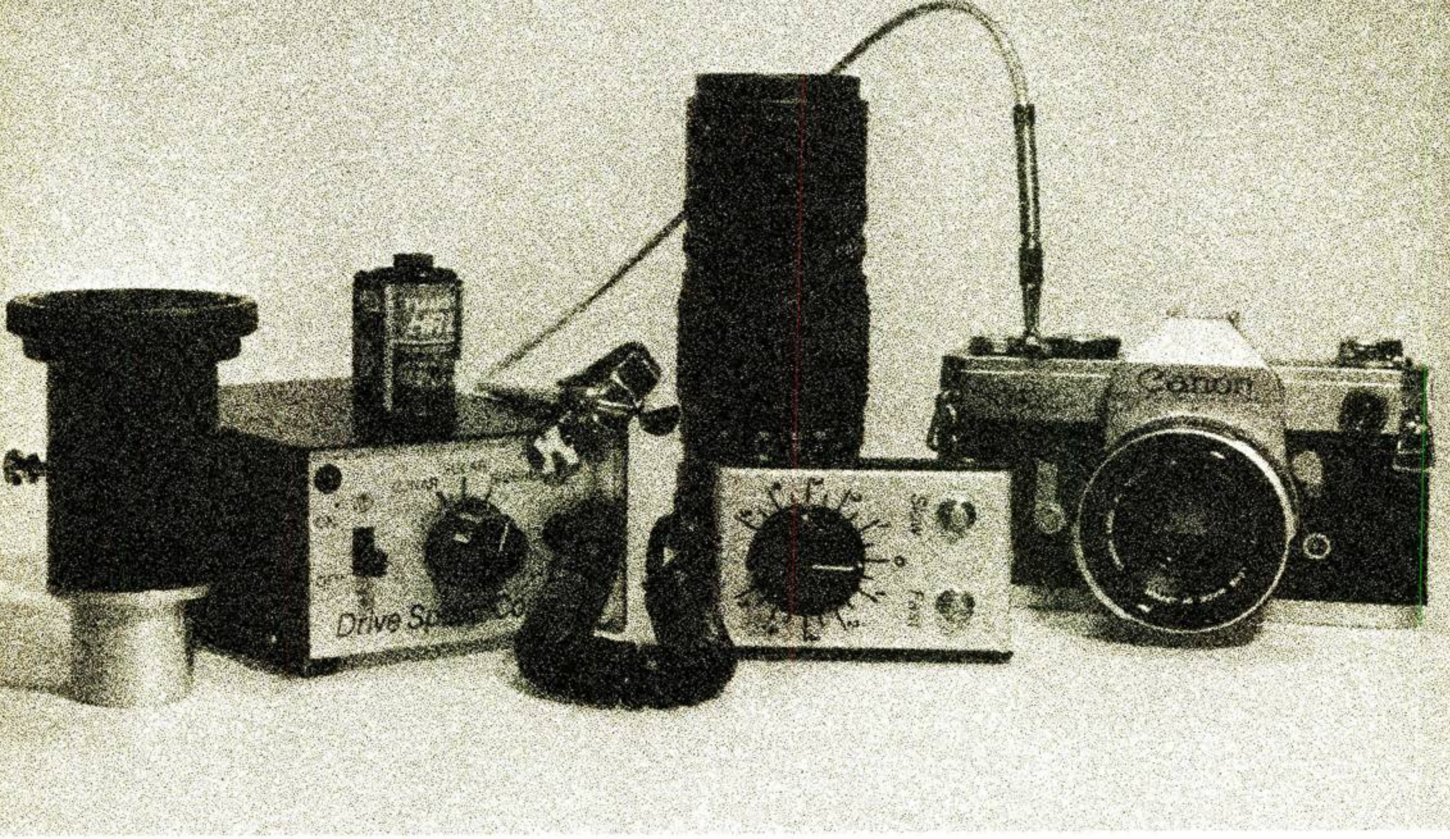
Photography
in
Astronomy

Fundamentals of Astrophotography

by
Mace Hooley



For most of us, obtaining good astrophotographs is at best difficult and frustrating. Capturing your favorite celestial object on film, whether it's Barnard's Loop or M31, is usually a trial-and-error process. Speaking from my own experience, I would say that there's more error than trial in it.

Beating Murphy's Law is best accomplished by letting someone else make the mistakes for you — hence my reason for writing this article. I've already made many mistakes. But I've learned a few things in the process that others who are just getting into astrophotography could benefit from knowing.

In this article, we'll cover the fundamentals of astrophotography, including the characteristics of film, setting up your camera and telescope, the pros and cons of guiding with a scope and off-axis guider, and polar alignment.

Film

Which to Use?

Let's begin where most would-be astrophotographers make their first mistake: film selection. Because we're photographing very faint objects against a relatively bright sky background, film speed and contrast are the most important factors to consider in choosing a film. Film speed is simply how fast an image records on film. Contrast is how images of different brightnesses are recorded on film. A high-contrast film will show a faint deep-sky object as distinct from the sky background; a low-contrast film will not.

Film speed also figures into contrast. Most high-speed films on the market have low-contrast emulsions designed mainly for terrestrial photography, which tends to be oriented to high-contrast lighting. Additionally, because film becomes less sensitive to light the longer you expose it (a factor known as reciprocity failure) fast, low-contrast films are often no more efficient than many of their slower, higher-contrast rivals.

Provided you're able to process and print your own color film, the films that present the best compromise between contrast and speed — as well as those most capable of producing the richest colors — seem to be Fujichrome 100 and the new medium-grained Konica SR1600. (Only a few months ago, Fujichrome 400 would have made this list. Unfortunately, the manufacturer has significantly lowered the film's sensitivity to red in order to accommodate the spectrum of conventional pictorial photography. As it now stands, Fuji 100 is actually more red-sensitive and exhibits contrast equal to or better than Fuji 400.)

These two films also respond extremely well to hypersensitizing, a process that significantly increases their speed and eliminates problems due to reciprocity failure. Over the last few years, "hypering" film has become one of the most popular methods of enhancing film performance. One of the most common

Astro Film Characteristics

Film	Contrast	Relative Speed	Grain
Kodak 1000	low	2.0	coarse
hypered	low	2.5	
cold camera	low	2.7	
Fuji 1600	low	2.2	coarse
hypered	low	3.2	
Konica SR1600	low	2.7	medium
3M 1000	medium	1.8	coarse
hypered	not recommended		
Tri X	medium	1.2	medium
cold camera	medium	2.0	
Ektachrome 400	medium	1.2	medium
hypered	medium	1.7	
cold camera	medium	2.3	
Fuji 100	medium	.7	fine
as negative	very high	1.4	
hypered negative	very high	2.0	
103a	very high	1.5	medium
hypered	very high	1.9-2.3	
2415	very high	.3	extremely fine
hypered	very high	2.3	extremely fine

methods of hypersensitizing film involves placing it in a vacuum to remove moisture, then soaking it in a chamber of forming gas (92% nitrogen; 8% hydrogen) for about three days. Hypering film reduces contrast somewhat, which is why it works best with emulsions that are initially high in contrast.

At the developing stage I advise against push-processing these films as this will increase the grain size but result in little or no increase in speed. The next time you see a salt-and-pepper print, ask the owner if his film was pushed!

Fujichrome 100 and Konica SR1600 both have excellent "red response" (emulsion layers that are sensitive to light emitted at the red end of the spectrum), which is important for recording emission nebulae, and "blue response" (emulsion layers sensitive to light emitted at the blue end of the spectrum), which is important for galaxies and blue reflection nebulae. The film of choice for systems slower than f/4 is Konica SR1600, which requires exposures of 15 to 30 minutes for excellent photos. (You can make up for the lack of contrast in this film by photographing through a contrast filter, especially if your exposures exceed about 10 minutes.) At f/4, Fuji 100 is the color-contrast and fine-grain champion; exposures should run 60 to 120 minutes under a dark sky. At f/2 and faster, a 30-minute exposure will yield outstanding images for Fuji 100.

If you want slides or don't want to bother with processing the film yourself, Ektachrome 400 is a good choice. Just expose for 10 minutes and have your favorite lab process the film normally — but be sure to tell the lab *not* to mount the film. The composition of an astrophoto can look quite alien to processors who are accustomed to pictures of people eating hot dogs at the beach. A dark-looking frame peppered with dots of light may be interpreted as some sort of unusual camera defect or photographer error. Unless you know that your processor will do a first-rate job, mount the frames yourself.

Hardware

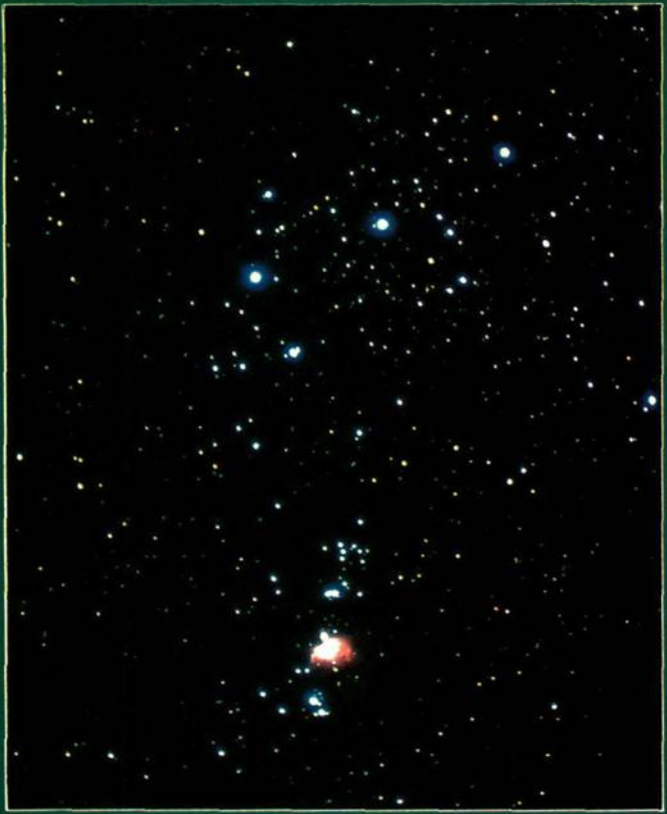
Now that you've chosen a film, what hardware will you need? When you first start out, use what you have. A camera on a tripod with a locking cable release is all you need to make excellent star trail and meteor photos or short-exposure constellation shots. Just load your camera with the film you have chosen, set it firmly on a tripod, open the lens to its widest f/stop, point it at the sky, and make a series of timed exposures ranging from about 20 seconds to 10 minutes. After the film is developed, you will notice that the short-exposure shots show the brightest stars plus a few not visible to the naked eye. The long-exposure shots will show a few more faint stars, but they will be arcs instead of points as a result of Earth's movement.

If your goal is to eventually take more detailed astrophotos — ones that show the fainter stars as sharp points — you will need to make guided exposures. The easiest way to do this is to mount your camera piggyback-style on any equatorially mounted scope. Guide through your main scope using a high-power eyepiece, keeping your guide star at the center of the field of view as you make your exposure. This will give you resolution on film of about an arcminute or so, which is fine for short focal-length camera lenses.

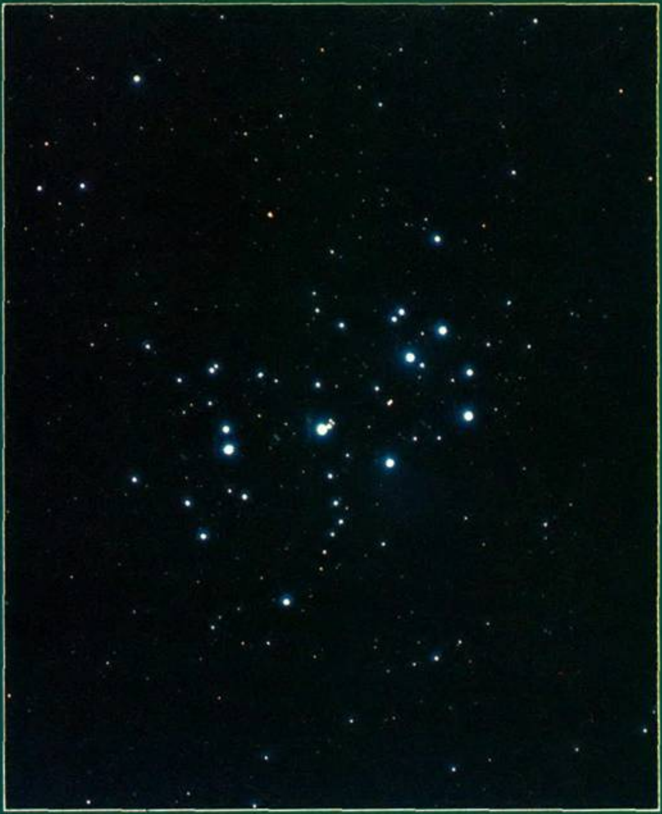
For shooting with telephoto lenses, you'll probably want an illuminated reticle eyepiece, a 2x or 3x Barlow, a declination slow-motion control, and a variable-frequency drive corrector. These will allow you to do the precision tracking necessary during long exposures. Notice that with piggyback photography, you're free to move the scope around to find a bright guide star while keeping your photographic field roughly centered in the camera.

What about shooting *through* your scope? For Moon and planetary conjunctions, a clock drive is helpful but not entirely necessary. Try some short-exposure prime focus photos first. (Move up to long-exposure photos when you feel you're ready). The requisites here are a drive corrector, a declination slow-motion control, and some means of guiding on a selected star. For simplicity, I recommend using a small refractor or long-focus reflector mounted in rings and bolted to your main instrument. A large guidescope is not necessary; use one that's light to lessen the load on your drive system.

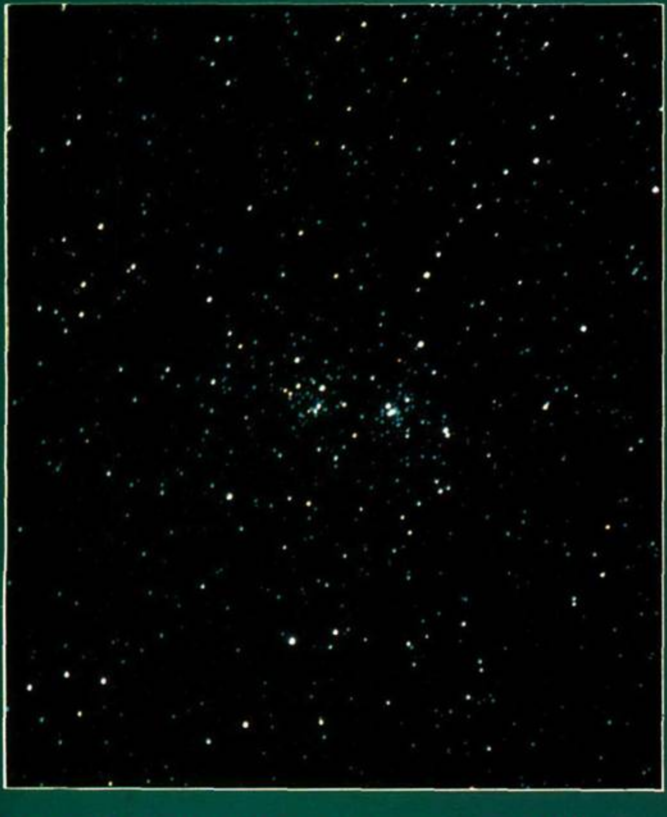
When guiding, use enough magnification to see the Airy disk (the disk-like image of a star in the telescope's field of view) and keep it centered on the eye-



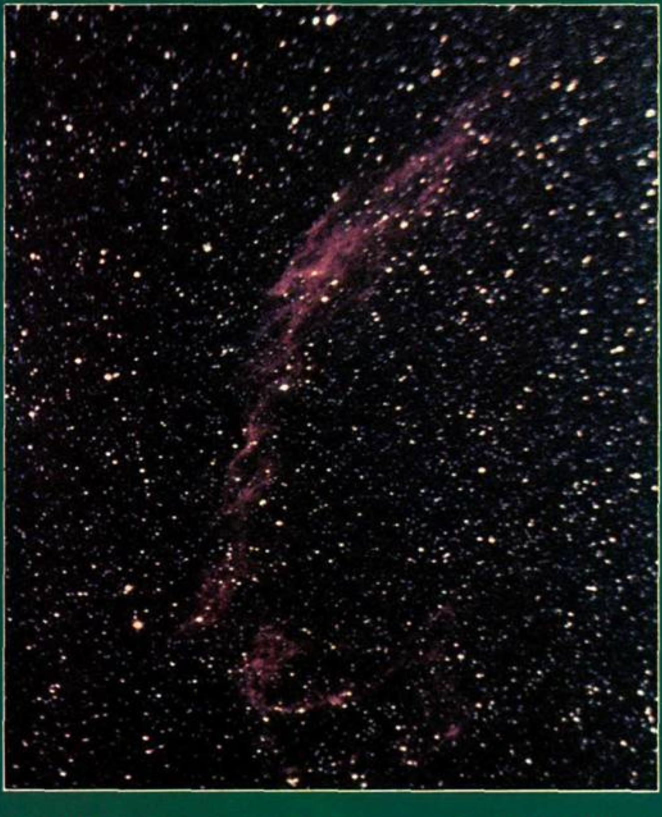
This familiar view of Orion's Belt and M-42 was taken through a 200mm f/3.5 lens for 19 minutes on Ektachrome 200 film pushed to ASA 400 and duplicated. Photo by Steven Wissler.



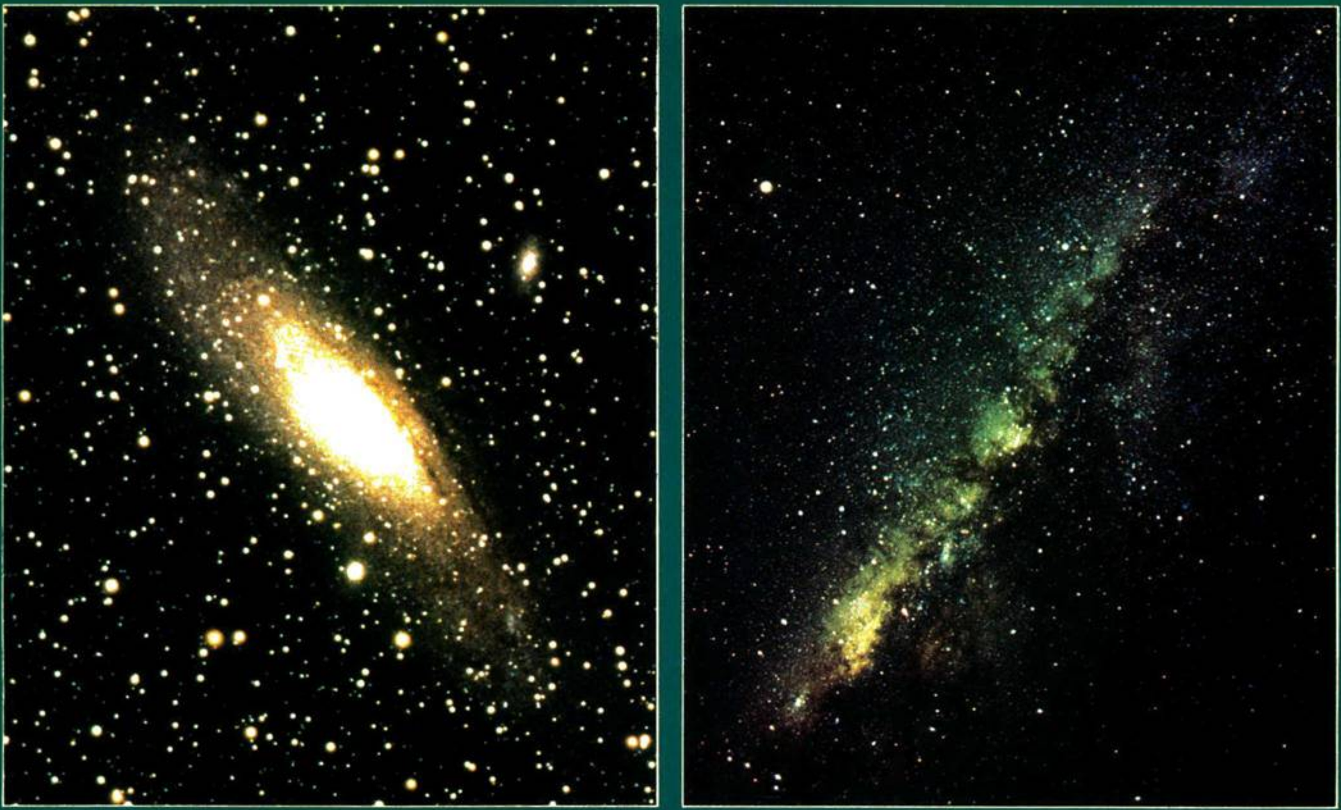
The Pleiades is an easy target for beginning astrophotographers. This shot was taken using a 400mm f/6.3 lens and GAF 500 film. Photo by C.L. Kussner.



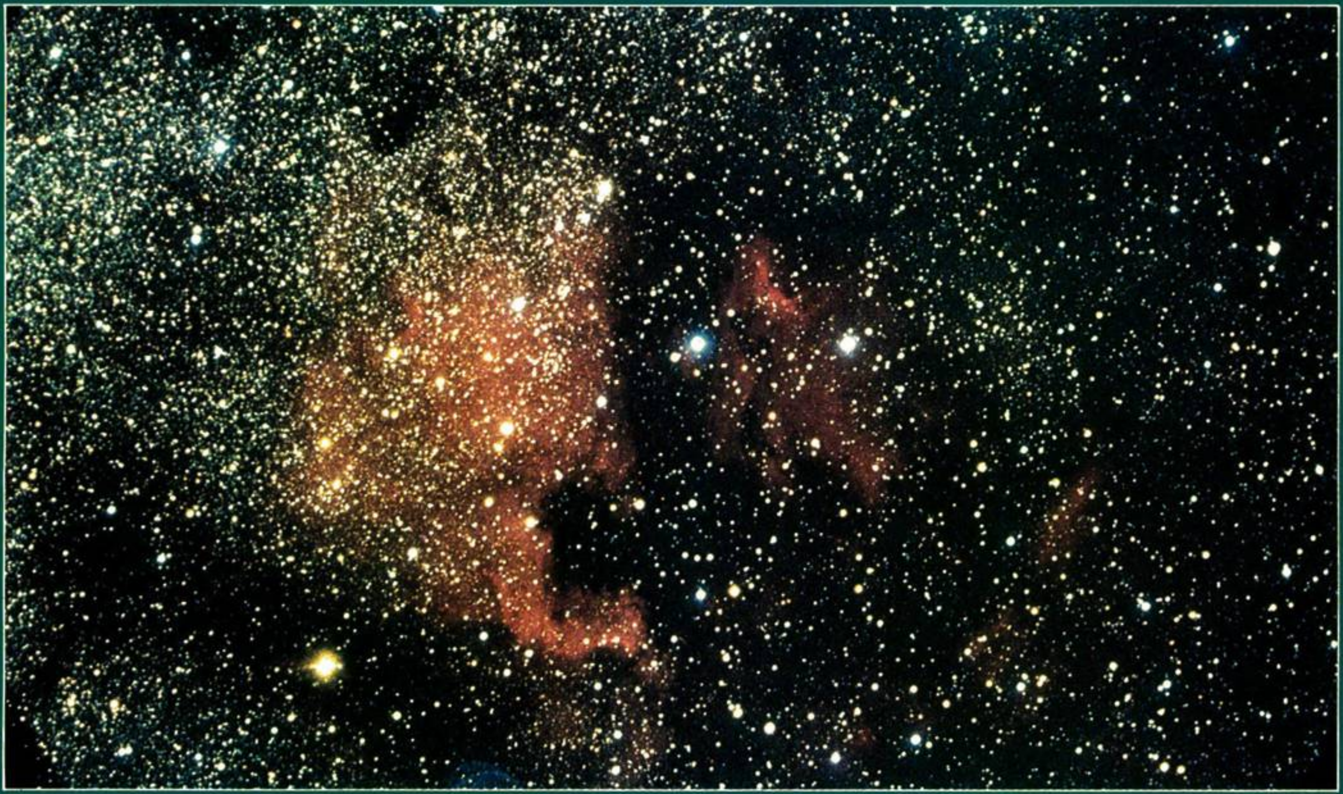
The Double Cluster in Perseus shot with a 300mm f/4 lens on Fuji R-100 film by David Healy.



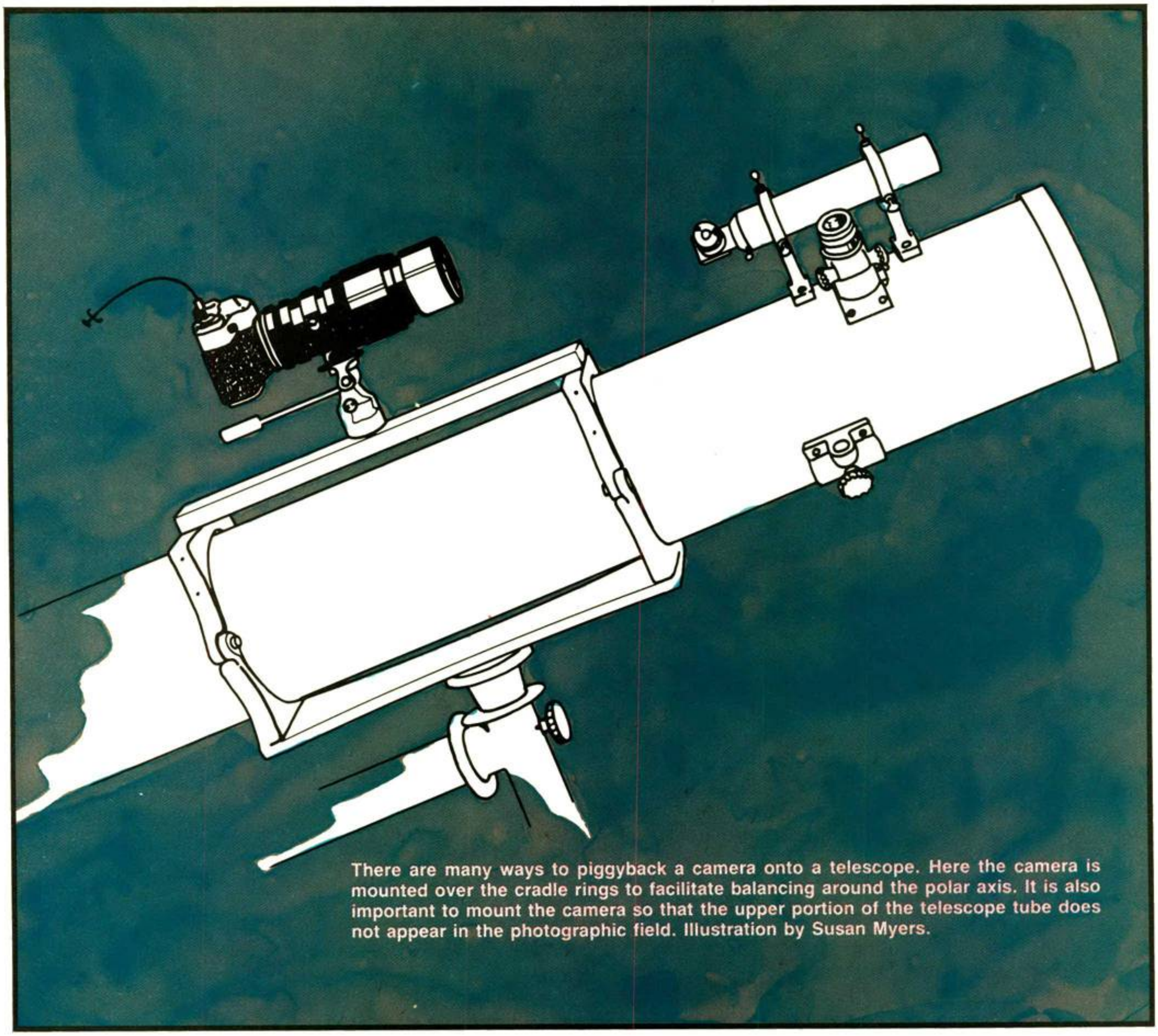
This 45-minute exposure of the eastern section of the Veil Nebula was taken through a 10-inch f/4.5 on the new high-speed film Konica SR1600 by Pierre Schwaar.



Two wide-angle exposures made with piggyback cameras on fine-grained Fujichrome 100 film. The Andromeda Galaxy (upper left) was exposed for 15 minutes through an 8-inch f/1.5 Schmidt camera. A 60-minute exposure of the Sagittarius-Scorpius Milky Way region (upper right) was taken with a 15mm f/3.5 lens. Jupiter appears in the upper left of photo. Photos by Mace Hooley.



Because of its large size, the North America Nebula is best recorded through a fast, wide-field, focal-ratio system. This photo was made with an 8-inch f/1.5 Schmidt camera during a 15-minute exposure on Fuji 100 film. The nebula can be similarly photographed using 200mm or 300mm piggyback telephoto lenses. Photo by Mace Hooley.



There are many ways to piggyback a camera onto a telescope. Here the camera is mounted over the cradle rings to facilitate balancing around the polar axis. It is also important to mount the camera so that the upper portion of the telescope tube does not appear in the photographic field. Illustration by Susan Myers.

piece cross hairs. In a 2.4-inch refractor at 120x, the Airy disk is about 2.5 arcseconds across; if you can guide to within two Airy disks, you have 5-arcsecond guiding capability. Three arcseconds is about the best resolution you could hope to get with an 8-inch Schmidt camera. In the end, it is necessary to guide only as accurately as your system can resolve on film.

What about guiding on the image produced by the telescope? Gizmos called "off-axis guiders" use a small mirror just outside the camera's field of view to intercept light from a guide star and relay it to the guiding eyepiece. The advantages here are less weight and the elimination of flexure (the bending of the guidescope relative to the main telescope). The disadvantages are greater expense and a restricted area around your photographic field in which to find a suitable guide star. This latter problem means that since you cannot see the object you are photographing, you must use what stars can be seen in the outlying areas of the photographic field and these are usually faint.

Personally, I have never had any detectable flexure between guidescope and astrocamera, and neither my 2.4-inch refractor nor my 4.25-inch Newtonian guidescopes have proven themselves too bulky. Nevertheless, if you think you're guiding perfectly but your exposures come out trailed, you may have a flexure problem. In that case, find out where the wobbly spots are on your telescope and firm them up or switch to an off-axis guider.

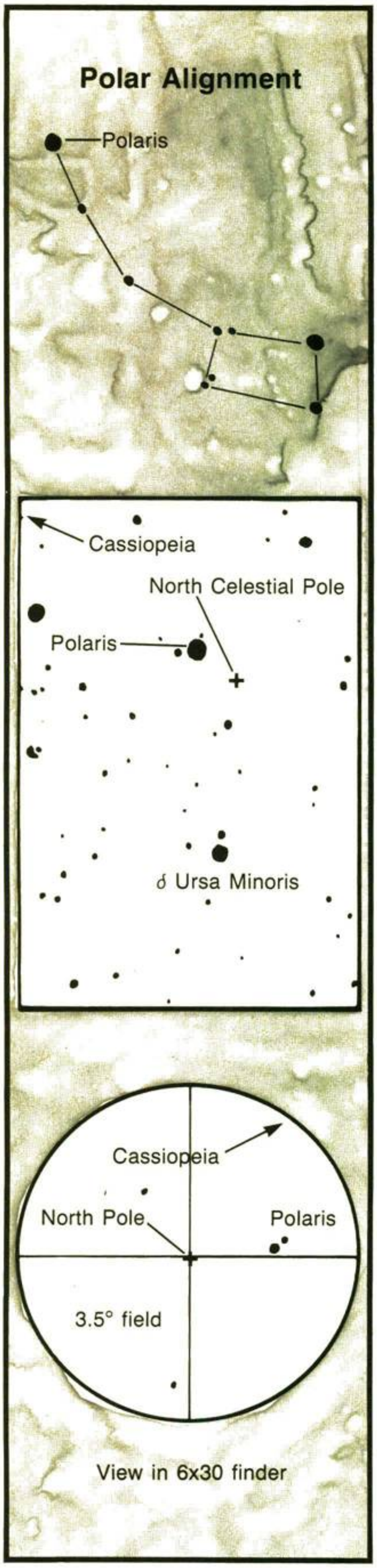
Guiding is one of the biggest challenges in astrophotography but one that has a very obvious advantage: the longer you can guide accurately, the longer you can make your exposures. One key to successful guiding is polar alignment. How precisely your telescope's polar axis is pointed toward the north celestial pole (the pivotal point for the north celestial sphere) will determine how accurately your telescope will track.

Polar Alignment

& Guiding

Here's a simple polar-alignment method for fork-mounted telescopes. (This method can also be used to some extent with German equatorial mounts.) Setting circles are helpful but not mandatory. Roughly align your scope toward Polaris. Set your telescope to 90° (tube parallel to the RA axis) and insert your lowest power eyepiece. Move the mount in altitude and azimuth to center on Polaris, and then lock down the declination axis.

Now, while looking into the eyepiece, rotate the right ascension axis about 100° and watch for the point about which the stars rotate. If all of the stars in the field do not move in concentric arcs, move



Point your equatorially-mounted telescope toward Polaris and center the north celestial pole in the field of view of your finderscope using this chart. Drawing by Susan Myers.

the entire mount in altitude and azimuth (without disturbing the declination axis) toward the center of rotation until it is in the middle of your field of view. This is the north celestial pole, which you want your polar axis to rotate around when your clock drive is engaged. Note that you won't be centered exactly on Polaris. This is because the true north celestial pole lies almost a degree away from Polaris in the direction of the end of the Big Dipper's handle. After you've done this procedure a few times, you'll be amazed at how quickly and easily you can get polar aligned.

Even small errors in polar alignment will eventually make themselves evident during guiding. Guiding on stars within the photographic field for short exposures will tolerate some polar-alignment error (but not much!) because it minimizes field rotation within the frame. Field rotation occurs when the telescope is not exactly aligned and instead of rotating around its polar axis rotates instead around the image.

The effects of field rotation become more evident the farther your guide star is from the frame and the greater the polar-alignment error is. This is why guiding on stars too far outside the photographic field is risky. Moreover, if you are guiding on a star more than a few degrees from your target, atmospheric refraction — the bending of light passing through Earth's atmosphere — can alter the apparent position of your guide star enough to introduce small tracking errors.

Of course, any polar-alignment error will be glaringly evident over long exposures whether your guide star is inside or outside the axis of the photographic field. The wisest thing to do, especially if you are planning on making long exposures, is to correct alignment errors revealed by test guiding. To do this, point the telescope at a bright star that is both near the celestial equator and the meridian. Using a high-magnification eyepiece with cross hairs, track the star until you notice drift either north or south (true sky directions) of the center of the cross hairs. If the star drifts north, your polar axis is too far west; if the star drifts south, your polar axis is too far east. Shift your mount in azimuth until drift is virtually eliminated.

Now point the telescope at a star situated about 20° above the eastern horizon and near the celestial equator. Again, track this star until you notice it drifting north or south in the field. If the star drifts north, the polar axis is too high; if the star drifts south, the polar axis is too low. Adjust the polar axis elevation until drift is eliminated. This type of polar alignment is obviously time consuming, so don't be surprised if it takes a couple of hours to eliminate the drift. Once done, however, you can feel more confident when tracking during long exposures, and guiding corrections you make will be small ones.

Additional Tips

Many astrophotos are ruined by focusing errors. One way to avoid this is to use a magnifier or small telescope (an old finderscope, perhaps) to help see the camera's focusing screen. Focus the image about a third of the way from the center of the screen.

The best way I've found to prevent focusing errors, though, is to focus the camera photographically. This method involves photographing a bright star using a one-second exposure at different focus settings near where you think the best focus is. Be sure to make a careful record of the focus settings for each exposure. After the film is processed, examine the star images with a magnifier to determine which is the sharpest, and then set your focus appropriately.

Remember that camera focusing screens are all off by a tiny amount, and precise focusing can only be done photographically. Accurate focus is a necessity; unfortunately, it is also one of the places where Murphy's Law can rear its ugly head. I have many photos that look like an explosion in a donut shop, some even made with my "permanently focused" Schmidt camera!

Also beware of nose and foot binaries. Bumping a scope during an exposure can create unwanted double stars by the dozens. And by all means, don't breathe on your front corrector lens; dew is always a problem, even if you live in the desert. To prevent dew, properly insulated nichrome wire can be wrapped around the front element or corrector and warmed with a 12-volt battery (see "Equipment Atlas," April 1985).

I use three 100-watt heating elements connected in series. Wrap two elements around the corrector plate and the third around the lens and eyepiece of the finderscope for a total power consumption of 33 watts. A 120-volt power supply comes in handy because sometimes a 500-watt hairdryer is the only thing that will defrost cold corrector plates or piggyback camera lenses. And by all means use a dew cap that is at least one aperture in length (and preferably longer).

Errant aircraft can be bothersome so keep an L-shaped piece of cardboard handy to cover the open end of the scope during an exposure. The cardboard can rest on the camera's front and usually will not disturb your fine alignment. The short time that your camera is covered to let an aircraft fly through the picture area will generally have no effect on your photograph. The same procedure is also useful for intermittent clouds.

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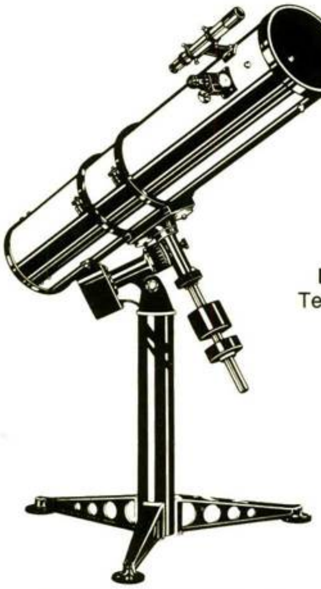

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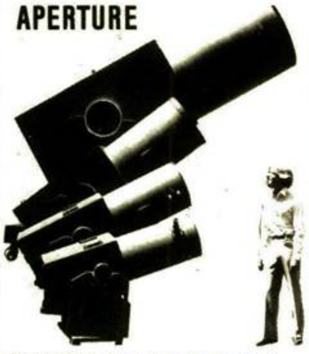

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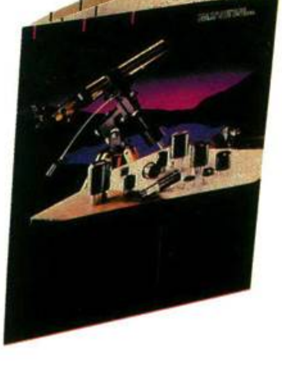

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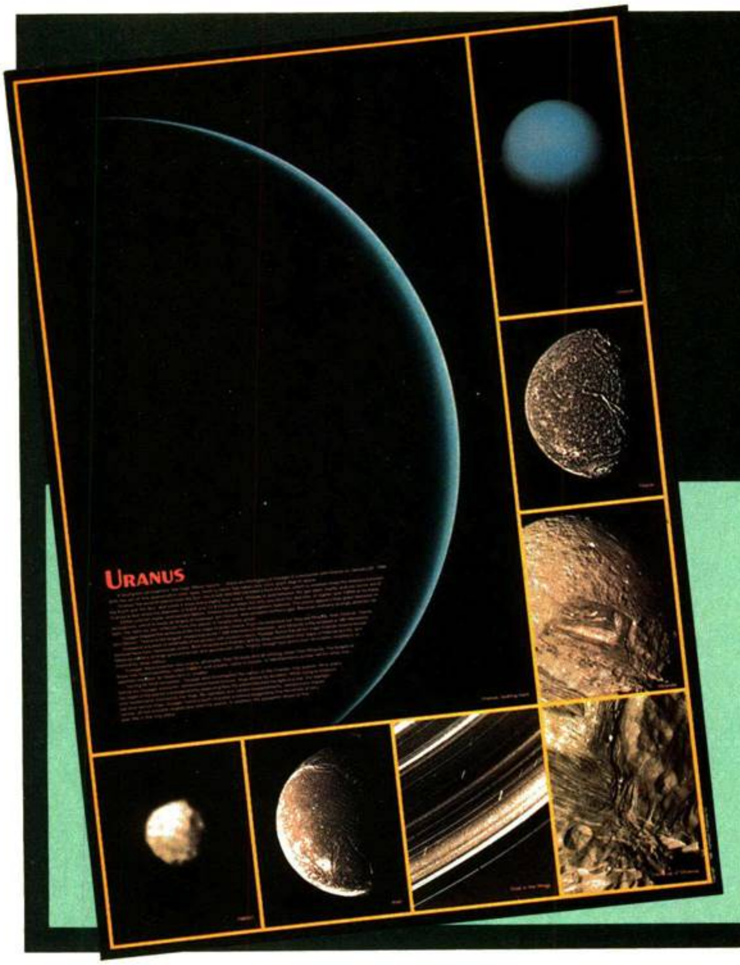

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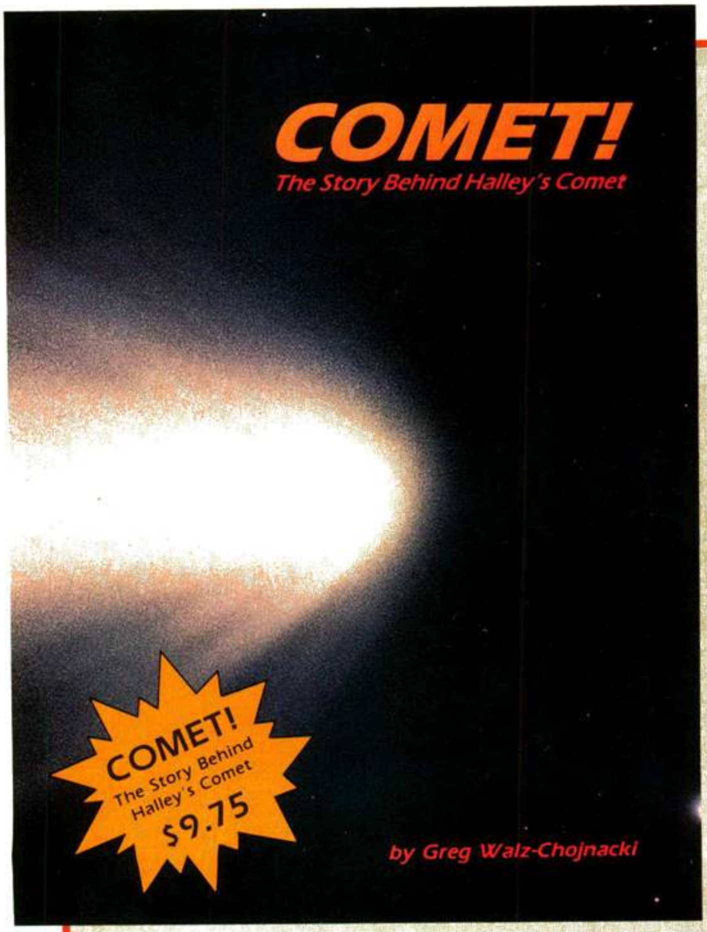
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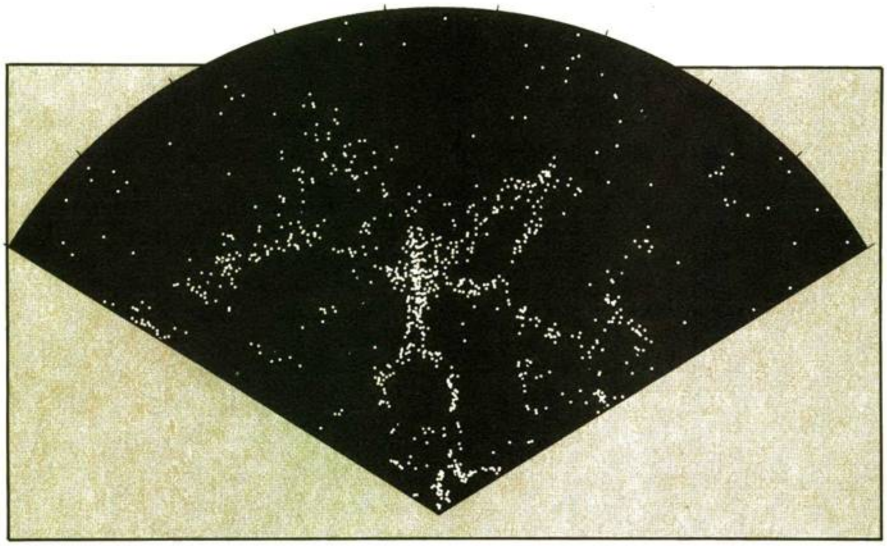

This 2-D representation of galaxy distribution has Earth at the vertex and galaxies (represented by dots) on the surfaces of giant bubble-like voids. The human-like figure at center of the diagram is the Coma cluster of galaxies.

A Bubbling Universe?

No more than a decade ago, virtually all astronomers believed the universe, at least on the large-scale, was homogeneous. There have been indications, however, that this might not be the case. Observations have shown large voids in the universe as well as galaxies clustered into long chain-like structures. Astronomers, though, have still been reluctant to abandon the concept of homogeneity. The most recent observations, however, seem to drive the nail even further into the coffin.

A three-dimensional map showing the distribution of galaxies in a small portion of the universe, presented at the January 1986 meeting of the American Astronomical Society in Houston, Texas, appears to show that galaxies lie on the surfaces of giant, bubble-like voids. The map's creators — John Huchra, Margaret Geller, and Valerie de Lapparent of the Harvard-Smithsonian Center for Astrophysics — propose that the universe is filled with these bubbles. In this view, the bubbles behave much like ordinary soap bubbles — the volume enclosed by each bubble is apparently empty and material, in this case clusters of galaxies, is concentrated at the intersections of these bubbles. These structures range in size from roughly 20 million to 50 million parsecs in diameter.

The 3-D map covers a section of sky 117 degrees long by 6 degrees wide in the general direction of the constellation Coma Berenices. Within this area, the researchers measured the redshifts of approximately one thousand galaxies. Since the redshift is a direct measure of a galaxy's speed of recession — and that speed is a direct result of universal expansion — knowing the redshift is equivalent to knowing the distance. Observing with the 1.5-meter telescope at Mt. Hopkins in Arizona, the survey includes galaxies located over 100 million parsecs from Earth.

A theory proposed in 1981 may be able to explain this new-found structure. Jeremiah Ostriker and Lennox Cowie suggested that a widely distributed, primordial generation of massive stars exploded less than one billion years after the Big Bang. Shock waves from these explosions then drove matter out of the voids and into the surrounding shells.

The new findings may also have important cosmological implications. If the voids are truly as empty as they now appear, the universe may be less dense than currently believed. This would add weight to arguments that the universe is open and will continue to expand forever.

The astronomers are now planning to search the same area for fainter galaxies, both to examine whether these bubble-like structures extend farther into the universe and to see if the voids are as empty as they currently seem. They also hope to extend their map to cover ten times the area of sky it now does in order to look for structure on a larger scale.

Did An Asteroid Create the Everglades?

For decades, the Florida Everglades have been recognized by geologists as a 1,700-square mile subtropical swamp dug out of the limestone bed by the eroding effects of groundwater.

But now evidence is mounting in favor of a cosmic explanation for the origin of the famous swamp. According to geologist Edward J. Petuch of Florida International University, The Everglades are the mud-filled remains of a crater that was created by an asteroid's collision with the ancient sea bed 38 million years ago.

There are a number of geological indications supporting Petuch's theory. In the 1940s, geologists noticed that the limestone bed beneath the swamp is covered with an extensive network of diverging fracture lines, similar to those a bullet hole makes in a glass window. The surface of the swamp appears to be punched out, leaving a depression that is evident in contour maps published by the Florida Bureau of Geology in 1974. Magnetic readings of the area indicate the presence of metallic ore beneath the mud, which could actually be the remains of the

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asteroid. In addition, the Ocala formation, a ubiquitous rock stratum of Florida, is not found in the extreme southern portion of the state. The reason for its absence, says Petuch, is because the formation was blasted into the sky upon impact by the asteroid.

Based on bore samples taken from the area, Petuch has developed the following scenario describing the formation of the Everglades. After the impact (which was centered about 35 miles southwest of where Miami is today), coral began to grow along the rim of the crater, eventually forming a nearly enclosed circular atoll. When the sea level rose, the coral sought warmer, shallower waters and migrated northward, elongating the atoll.

Eventually the inland sea was cut off from the ocean by the rising coral walls. Sediments began to collect, shrinking the brackish lagoon's size. In time, fresh water filled the basin, and under the warm southern sun grasses began to proliferate. In the millions of years that followed, this large inland lake shrank further until it measured roughly 30 by 40 miles across. Today, Lake Okeechobee, Central Florida's largest body of water, is the last vestige of that inland lake.

Milky Way Site of Radio Threads and Jets

Recent observations of the galactic nucleus have revealed the existence of two new radio emission structures, adding to the growing list of phenomena being discovered at the center of the Milky Way.

Writing in the December 1985 issue of the *Astronomical Journal*, Mark Morris of the University of California at Los Angeles and Farhad Yusef-Zadeh of Columbia University report the presence of three long, narrow, thread-like features. These "threads," each more than 30 parsecs long but only about 0.5 parsecs across, are located just north of Sagittarius A, the radio source identified as the core of the Milky Way. The observations were taken with the Very Large Array radio telescope in Socorro, New Mexico.

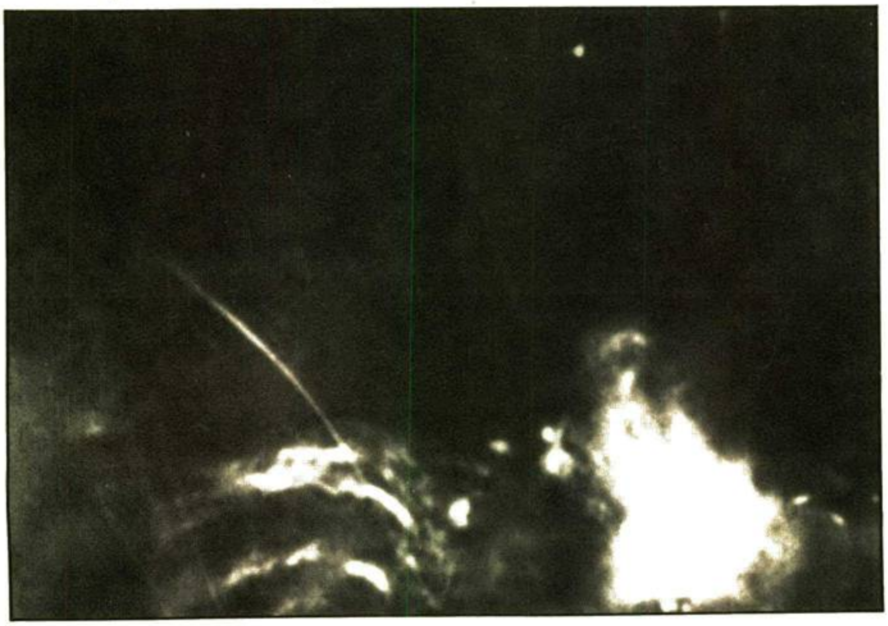
This type of structure has never been seen before and, at the moment, its physical nature remains unexplained. Several possibilities, however, can be eliminated. The uniform brightness of these structures precludes the possibility that they might be shock fronts resulting from a galactic explosion; gaseous jets produced in the Galaxy's nucleus are not feasible because there is no obvious source for any of the threads; and wakes left behind by a rapidly moving, massive object are ruled out since the curvature of the threads does not match the expected wake pattern.

The most plausible explanation is that the threads are magnetic structures in which flowing gas is restricted to narrow channels by the galactic magnetic field.

More understandable than the threads is the second structure, which has been tentatively identified as a galactic jet. Morris and Yusef-Zadeh, in collaboration with O.B. Slee and G.J. Nelson of Sydney, Australia, report in the January 15, 1986, issue of *Astrophysical Journal Letters* on observations made with the Culgoora Radioheliograph in Australia. The data show a jet of low-frequency radio emission streaming south from the core along the Galaxy's axis of rotation.

Unlike the threads, radio jets have been observed before in several edge-on spiral galaxies and, more frequently and at

Two newly found galactic threads are visible in this Very Large Array image. The more prominent thread is at middle-left, with the dimmer one curving through the middle of the image. Sagittarius A is the bright feature at lower-right. Photo courtesy Mark Morris.



higher energies, in active galaxies and quasars. If confirmed, the Milky Way's jet is further evidence supporting the idea that a supermassive black hole resides at the center of our galaxy.

New Determination of Hubble's Constant

Since the discovery of the expanding universe earlier this century, astronomers have been seeking ways to pinpoint its rate of expansion. Known as Hubble's constant (H_0), this rate is notoriously difficult to measure since it demands a knowledge of the distance to far-off galaxies. The constant has enormous value, however, because it gives us information about the age of the universe, its structure, and its possible future.

A group of researchers, reporting in the November 7, 1985, issue of *Nature*, have employed a promising new technique for determining Hubble's constant. Led by Norbert Bartel of the Harvard-Smithsonian Center for Astrophysics, the method requires combining the distance and observed recessional velocity of an extragalactic supernova. The current study concentrated on the supernova 1979c in the large spiral galaxy M-100, which is located in the Virgo cluster of galaxies.

To calculate the supernova's distance the team had to know both how fast the angular diameter of the exploding star was increasing and the actual velocity of expansion. The angular diameter was measured by the most sensitive technique known: very-long baseline interferometry (VLBI). Using an array of up to nine radio telescopes to make observations over an eighteen-month period, the researchers determined that the supernova has expanded to an angular diameter of approximately one-thousandth of an arcsecond some four years after the explosion. The actual velocity of expansion, determined optically, is known to be on the order of 10,000 kilometers per second.

By assuming reasonable models for the brightness distribution of an expanding supernova and for the relationship between the radio and optical emission, the distance determination becomes a simple problem in geometry. The calculation yields a value of 19 megaparsecs (Mpc) for the distance to the Virgo cluster.

Once the distance is known, computing Hubble's constant is simply a matter of knowing the rate at which the Virgo cluster is receding from our own Local Group of galaxies. The current study comes up with a value of H_0 = 65 km/sec/Mpc, which is in agreement with other recent studies.

The authors believe the accuracy of this figure can be improved by following SN1979c for a longer period of time as

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well as by including more widely spaced radio antennas in the VLBI array. Furthermore, about one supernova per year should be detectable with this setup in the coming years, allowing distance determinations for galaxies out to 40 Mpc. From these results, we can look forward to a more statistically significant value for Hubble's constant.

17th-Century Nova Indicates Novae are More Numerous than Estimated

The rediscovery of Nova CK Vulpeculae (CK Vul) — now 40 million times fainter than when it last flared three centuries ago — has raised the possibility that novae may be ten times more numerous than commonly thought. The story behind this finding was reported in the July 1, 1985, *Astrophysical Journal* by Ronald Webbink of the University of Illinois, Michael Shara of the Space Telescope Science Institute, and Anthony Moffat of the Universite de Montreal.

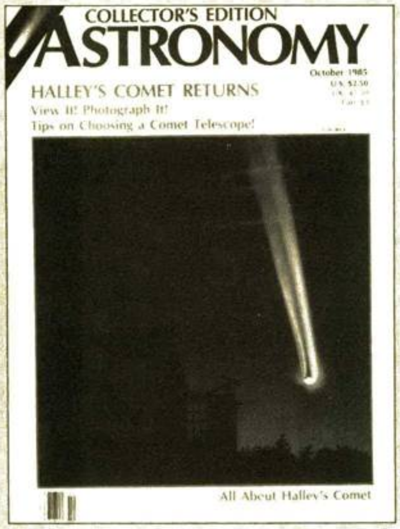
CK Vul was first observed in 1670 and remained visible to the naked eye for two years. After reaching a magnitude of 2.6, the nova faded below naked-eye visibility and was eventually lost.

By digging through old astronomical records, in particular those of 17th-century Polish astronomer Johannes Hevelius, Webbink was able to get an accurate position for the nova. From his findings, Shara and Moffat successfully relocated CK Vul in 1982.

Novae are generally believed to occur in binary systems consisting of a normal star and a white dwarf in close orbit. The outer layers of the normal star are drawn off by the white dwarf and accumulate on its surface. As the dwarf's weight increases, so does its temperature until a critical value is reached and the gas undergoes rapid fusion. This explosive event causes a swift increase in brightness — what we see as a nova. Following the explosion, gas again starts accumulating, repeating the process.

Typical novae fade by a factor of 10,000 to 1 million from their peak brightness during this quiescent phase, implying that an average of 1,000 to 10,000 years elapse between outbursts. CK Vul, however, is now 40 million times fainter than it was at its peak — by far the dimmest example known. From this observation, the researchers estimate that CK Vul only flares once every 100,000 years.

If the behavior of CK Vul between eruptions is typical of novae in general, then current estimates of their numbers and space densities may be ten times too small. The only way to know for sure is by finding other ancient novae. Novae that occurred in 1612, 1673, and 1678, and have not been seen since, could hold the key to answering this question.



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May 9-10
Microcomputers in Physics and Astronomy, Valdosta State College, Valdosta, Georgia. Contact: Dr. Dennis Marks, Dept. of Physics, Valdosta State College, Valdosta, GA 31698.

May 10
Twelfth Annual Convention of the Virginia Association of Astronomical Societies, Roanoke, Virginia. Contact: K. Reed Thompson, General Chairman, VAAS Convention, 4528 Wyndale Ave. SW, Roanoke, VA 24018. Phone (703) 989-9402.

May 16-18
Annual Meeting and Conference of the Royal Astronomical Society of New Zealand, Palmerston North, New Zealand. Contact: Noel Munford, President, Palmerston North Astronomical Society Inc., Centennial Observatory, Anzac Park, P.O. Box 398, Palmerston North, New Zealand.

May 22-25
Riverside Telescope Maker's Conference, Camp Oaks, Big Bear, California. Contact: Cliff Holmes, 8642 Wells Ave., Riverside, CA 92503. Phone (714) 689-6893.

May 23-26
Fifth Annual Space Development Conference, Seattle, Washington. Contact: 1986 Space Development Conference, Dept. C3, P.O. Box 30869, Greenwood Post Office, Seattle, WA 98103.

May 26
IAPPP Annual Big Bear Symposium, Camp Oaks, Big Bear Lake, California. Contact: The Reverend Donald L. Rohe, 957 W. Marshall Blvd., San Bernardino, CA 92405. Phone (714) 883-7923.

June 19-21
IAPPP Symposium on Photoelectric Photometry, Mercyhurst College, Erie, Pennsylvania. Contact: Robert C. Reisenweber, Rolling Ridge Observatory, 3621 Ridge Parkway, Erie, PA 16510. Phone (814) 899-2560.

June 22-27
168th Meeting of the American Astronomical Society (professional meeting), sponsored by Iowa State University, Ames, Iowa. Contact: AAS, 1816 Jefferson Pl., N.W., Washington, DC 20036.

June 27-30
Royal Astronomical Society of Canada General Assembly, Winnipeg, Manitoba, Canada. Contact: Lorence Mlodzinski, Registration Committee, R.A.S.C. General Assembly 1986, P.O. Box 174, St. James Post Office, Winnipeg, Manitoba, Canada R3J 3R4.

June 29-July 4
International Planetarium Society Eighth Biennial Conference, Tucson, Arizona. Contact: IPS Conference Committee, Flandrau Planetarium, University of Arizona, Tucson, AZ 85721. Phone (602) 621-4515.

July 11-13
Annual Convention of the Northwest Region of the Astronomical League (sponsored by the Seattle Astronomical Society), Seattle, Washington. Contact: Bob Suryan, Seattle Astronomical Society, 6710 - 4th Ave. NW, Seattle, WA 98117. Phone (206) 789-0599.

July 11-13
16th Annual NFCAAA Summer Seminar, Darling Hill Observatory, Vesper, New York. Contact: Denise Sabatini, 342½ Chestnut St., North Syracuse, NY 13212. Phone (315) 458-1454 evenings and weekends.

July 12-17
98th Annual Meeting of the Astronomical Society of the Pacific, University of Colorado, Boulder, Colorado. Contact: A.S.P., 1290 24th Ave., San Francisco, CA 94122. Phone (415) 661-8660.

July 16-24
Space Week '86. Contact: James B. Harris, Jr., Florida Space Week Committee, P.O. Box 291, Sharpes, FL 32959. Phone (305) 632-9139.

July 24-27
Yellowstone's Night Skies (4-day course), Yellowstone National Park, Wyoming. Contact: Gene Ball, Yellowstone Institute, P.O. Box 117, Yellowstone National Park, WY 82190. Phone (307) 344-7381 ext. 2384.

July 31-August 4
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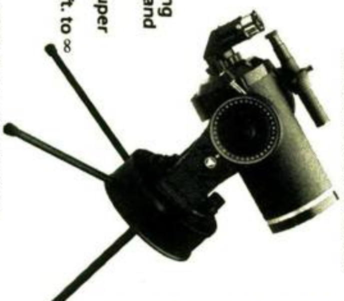

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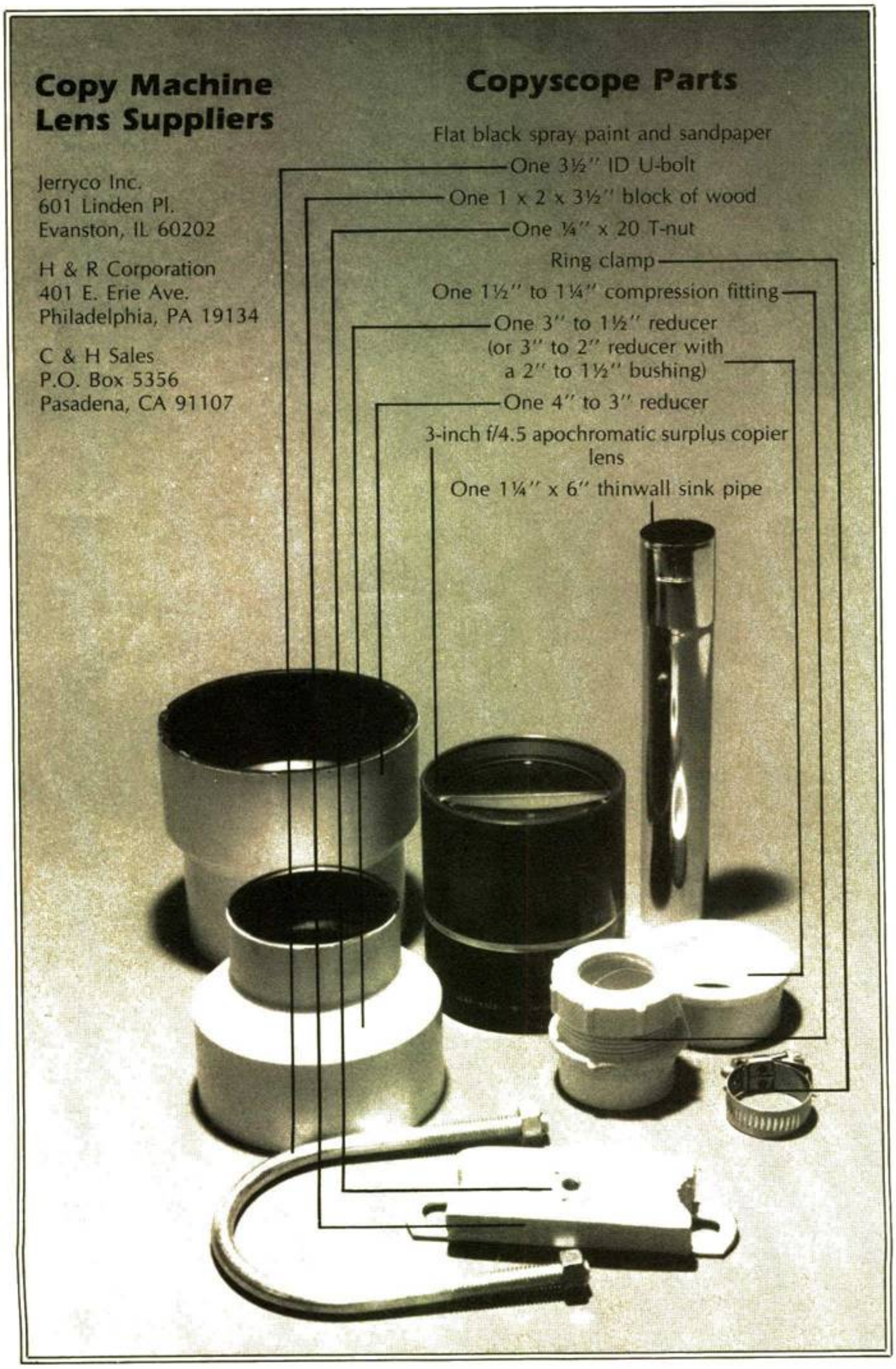
Equipment Atlas

Building a Copyscope

by
Ken Bird



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Copyscope Parts

Flat black spray paint and sandpaper
One 3½" ID U-bolt
One 1 x 2 x 3½" block of wood
One ¼" x 20 T-nut
Ring clamp
One 1½" to 1¼" compression fitting
One 3" to 1½" reducer (or 3" to 2" reducer with a 2" to 1½" bushing)
One 4" to 3" reducer
3-inch f/4.5 apochromatic surplus copier lens
One 1¼" x 6" thinwall sink pipe

I have always wanted the wide-angle advantage of a low-power richfield telescope (RFT) but without the disadvantages inherent in the commercially available models. Reflectors can be unwieldly and, if they aren't constructed well, require frequent collimation. Quality refractors in the 60 to 80 millimeter range work well but are too expensive.

One day while picking up some plumbing material at my local hardware store, it occurred to me that PVC pipe would make excellent telescope material, especially if the objective could fit snugly inside a coupling or reducer. Such an instrument began to take shape in my mind as I stood over the plumbing bins: it would be a durable little RFT that would be inexpensive but not unattractive. And it would be easy to build.

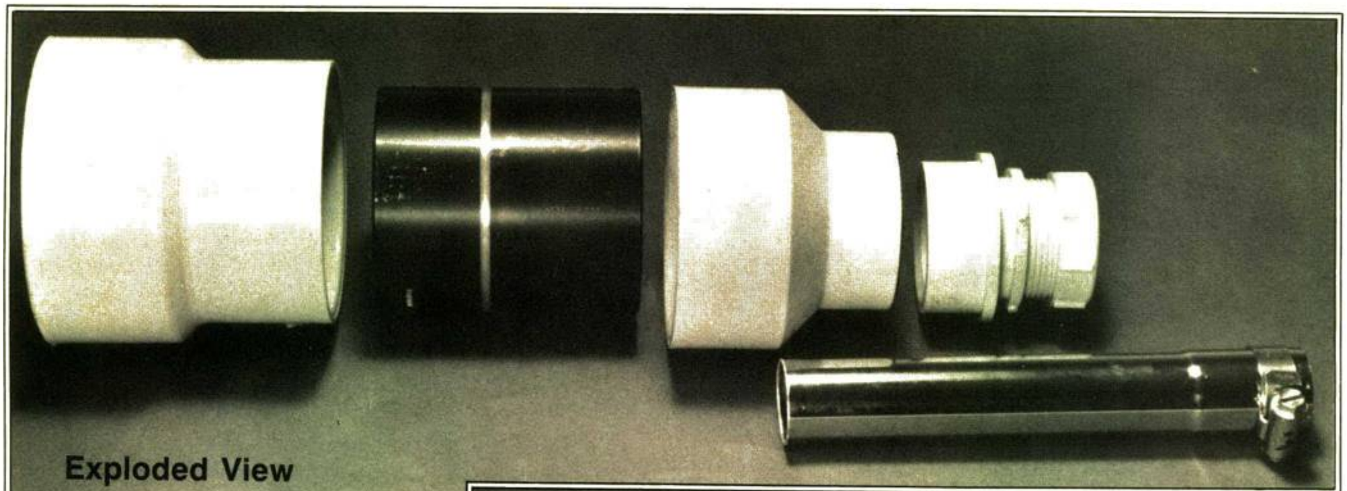
I investigated what was available in the way of suitable objective lenses from surplus dealers, finally obtaining a copier lens of excellent quality. Then I returned to the hardware store and purchased the rest of the items. The resulting instrument has performed so well that I want to share its construction with others.

Collecting the Parts

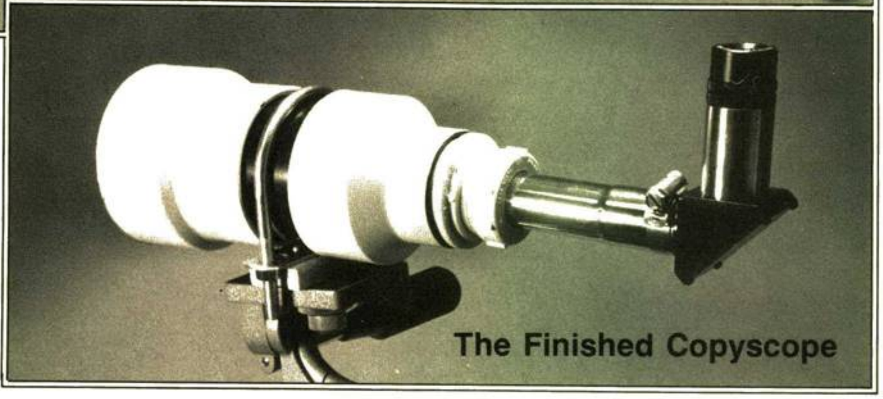
The lens for this scope is a 3-inch f/4.5 six-element copier lens with a very sharp, flat field. It comes already mounted in a 3.5-inch-diameter steel cell that lends itself well to use with PVC pipe. The lens was purchased from Jerryco Inc., of Chicago under their catalogue number J3597 (see parts list). Other scientific surplus suppliers may have this same lens, but you should check the lens specifications in their catalogues carefully.

After purchasing the lens, inspect it for any obvious defects. I spent a very interesting afternoon removing dirt particles from in between the lens elements. Most lenses, however, will only need their exterior surfaces cleaned. Be sure to whisk grit from the surface with a soft lens brush before cleaning it with a silicate-free cloth or your new lens will sport a few damaging scratches.

The remaining parts for the scope can be obtained from the local hardware store.



Exploded View



The Finished Copyscope

First, visit the plumbing department and ask for the following items: two PVC sewer pipe reducers, one 4″ to 3″ and another 3″ to 1½″ (note: reducer fittings are commonly referred to as 4″ x 3″, 3″ x 1½″, etc.); one 1½″ to 1¼″ PVC compression fitting; and one 1¼″ x 6″ thinwall sink pipe.

PVC pipe comes in a wide variety of fittings and sizes. For example, if you can't find a 3″ to 1½″ reducer, you can use a 3″ to 2″ reducer and bring it down to 1¼″ by inserting the proper bushing and gluing it into the compression fitting using PVC pipe glue. The added fitting will not significantly alter the length of the telescope, but adapting it is a bit more work.

From the nuts and bolts bin, ask for a 3½″ ID U-bolt assembly and a ¼″ x 20 T-nut. Next, have the lumber department cut a 3½″ length of 1 x 2 pine (or buy a short length and cut it yourself); make sure the wood is not cracked or warped. Some flat black spray paint will round out the necessary supplies.

Constructing the Telescope

Lay out the PVC parts on your work bench with the large reducer wide-end down and the smaller reducer placed on top. Note how they already resemble a telescope, with the larger reducer forming the front cell and dew cap and the smaller reducer making up the rear cell and focus-assembly holder. With masking tape and newspaper, cover the reducers so that the front inside of the large reducer (dew cap) and the rear inside tapered part of the smaller reducer (focus) can be painted flat black. After painting, set the reducers aside to dry and proceed to the drawtube and holder assembly.

Make a drawtube from the 1¼″ thinwall sink pipe. Start by hacksawing ½″ off of the end opposite the flare. You may also want to make a small T-cut in the flared end so that a ring clamp can be used to firmly grasp an inserted eyepiece or diagonal. I used an Amici-type star diagonal; although any type will work, the light-path length may vary. The focal length of the lens (measured from the middle part of the six-element lens to the focus) is 11″ (280mm), but the distance from the rear surface of the lens to the focus is approximately 9″. Experiment with the drawtube length in order to match it to your diagonal, but be sure that it isn't so long that it touches the lens. Take out the nylon washer from the compression fitting and slip the knurled part of the fitting onto the drawtube with the threads opposite the flared end. Now pull the nylon washer over the drawtube and push it down into the knurled fitting. It may be necessary to ream out the nylon washer a bit to get a smooth yet snug movement of the drawtube.

When the paint is dry on the PVC reducers, assemble the scope body. Lay the front reducer wide-end down and place the lens front-end first into the reducer. If it does not go in at all, use sand paper on the inside of the reducer wall until the lens slips in snugly enough so that it can't be easily removed. (Too tight is better than too loose.) Slip the rear reducer onto the back end of the lens, again making any adjustments to the reducer wall with sandpaper. Properly seated, there should be a ⅜″- to ⅞″-gap between the reducers. This gap is where the U-bolt will fit.

The Tripod Mount

I devised a simple tripod mount for the scope by using a 3½″ ID U-bolt. Drill two ⅛″ holes in the U-bolt's flat metal retainer ½″ in from each elongated bolt hole. Take the 1 x 2 block of wood, mark the center, drill a 3⁄16″ hole into it, and tap the ¼″ x 20 T-nut into the hole. You may want to countersink the T-nut so that the threaded portion is nearly flush with the outside of the wood. Next, mount the block on the retainer with wood screws. Slip the U-bolt over the scope and install and tighten the retainer. If your piece of 1 x 2 is a bit too long within the U-bolt, you can either cut off some of the extra length or rout out grooves on each end for the bolt to pass through, which also allows for easy tightening of the nuts.

Now you are ready for testing and evaluation of your scope.

Testing the Scope

Insert the compression fitting with the drawtube into the rear reducer. The drawtube will fit tightly yet can be removed by carefully rocking it out. Using a suitable daylight target (I found a traffic light two blocks away to be sufficient), insert your star diagonal equipped with a low-power eyepiece into the drawtube. Move the drawtube back and forth until you find the best focus. If you cannot get your scope to focus this way, it probably means your sink pipe is too long. Try handholding the eyepiece in the focal area to get an idea of how much sink pipe you need to cut off. However, be sure that your final drawtube length accommodates all of the eyepieces you want to use with the scope.

While primarily a low-power, wide-field instrument, the copyscope provides good lunar and planetary views with a 5mm eyepiece. For the money invested — about $30, not including the diagonal, eyepieces, and tripod — the performance of the copyscope is excellent.

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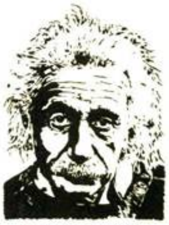

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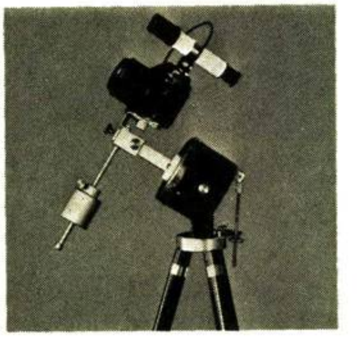

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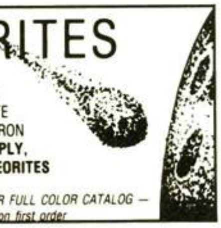

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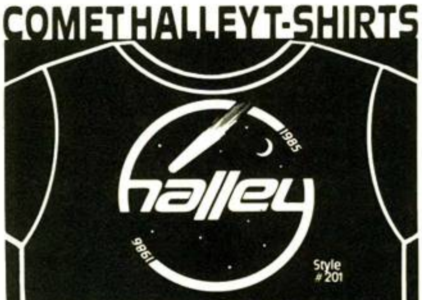

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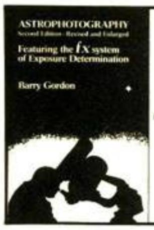
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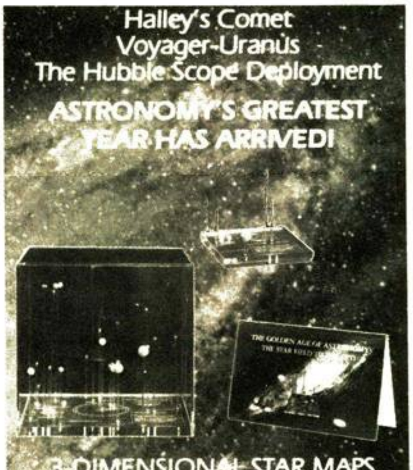
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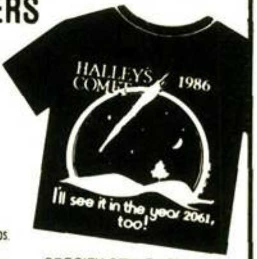
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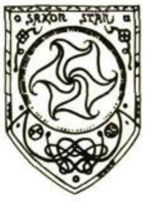

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Europe's Place in Space: Number Three and Growing

By Philippe Van Nedervelde

Although you wouldn't know it from the major media, the American/Russian monopoly in space exploration has come to an end. Europe, in the form of the thirteen-nation European Space Agency, has made significant contributions to space science and exploration, including the recent Giotto mission to Comet Halley. Both independently and in cooperation with other space agencies, Europe is attaining a level of expertise and autonomy in its scientific projects that will continue to grow into the 21st century.

In comparison to NASA, the European Space Agency (ESA) is a youngster. It was formed in May 1975 to consolidate the activities of the European Research Organization and the European Launcher Development Organization. Member states include Austria, Belgium, Denmark, France, West Germany, Ireland, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom.

The agency's tasks, as stated in its convention adopted in 1980, are "to provide and promote, for exclusively peaceful purposes, cooperation among European states in the fields of space research and technology, with a view to their scientific purposes and for operational space application systems." To achieve this overall goal, ESA implements a long-term space policy, recommends space objectives to member nations, and coordinates the policies of member nations.

ESA also funds many scientific projects as well as communications and meteorological satellite programs. In 1985, the agency's funding amounted to approximately $800 million. Member states contribute to the agency in proportion to their average national income calculated over the past three years. However, participation in specific projects is optional. France, for example, was the primary sponsor for development of the Ariane launcher, and Germany has taken the lead for Spacelab funding.

ESA operates facilities throughout Europe and the world from its headquarters in Paris. The European Space Operations Center in Darmstadt, West Germany, is in charge of all satellite operations and ground facilities. The European Space Research Institute (ESRIN) is located in Frascati, Italy, near Rome and operates the Information Retrieval Service and the Earthnet satellite program. The European Space Research and Technology Center at Noordwijk, Netherlands, is responsible for applied research in space technology and for design, development, study, and testing of spacecraft.

In an effort to increase Europe's role as a leader in scientific research, ESA has developed a long-range program to guide it through the remainder of the century. The four "cornerstones" of this program outline the essential goals that ESA will pursue in its mission planning.

The Solar/Terrestrial Physics Program builds on Europe's experience in studies of the Sun-Earth system, which includes the interplanetary medium, Earth's magnetosphere, and space plasma physics. The Ulysses mission, which will study the Sun from a new perspective outside the ecliptic plane, is the most recent mission in this continuing program. Planning has recently begun on two other projects scheduled for launch in the early 1990s: Soho (Solar and Heliospheric Observatory), which will study the outer layers of the Sun and the solar wind streams; and Cluster, which will study the Earth's plasma environment.

The Primitive Body Mission will follow up Giotto's Comet Halley encounter with a comet/asteroid rendezvous that will return material to Earth from these unique solar system objects.

The remaining two cornerstones look beyond our solar system into the far reaches of the universe. The High Throughput X-Ray Spectroscopy Mission will conduct spectral studies of objects with low surface brightnesses; and the Heterodyne Spectroscopy Mission will examine the unexplored region of the electromagnetic spectrum between infrared and radio radiation.

ESA is pursuing these goals with other agencies, such as

NASA, as partners. One cooperative project currently under discussion is the Cassini mission to Saturn in which NASA would provide a spacecraft to study Saturn and ESA would piggyback a probe to investigate the atmosphere of the moon Titan.

Current Satellite Missions

The diversity and importance of Europe's contribution to space science is evident from the wide range of missions that ESA is currently involved in. These projects include cooperative missions with NASA as well as missions that have gone where NASA did not go.

Giotto. This mission to Halley's Comet was ESA's first interplanetary project. Launched on an Ariane 1 rocket in July 1985, the spacecraft's prime objective was to detect the nucleus of the comet during its very close encounter with the comet on March 13, 1986. Giotto ventured within a few hundred kilometers of Halley's nucleus to study its composition and structure.

The spacecraft, weighing 2,100 pounds at launch, carried ten scientific instruments: a camera for photographing the nucleus, three mass spectrometers for analyzing the chemical and isotopic composition of the comet's dust and coma, several dust impact sensors, a photopolarimeter, and a battery of plasma sensors.

During its flight toward Comet Halley, Giotto measured the solar wind and its composition. The camera also photographed Jupiter, Earth, and the star Vega.

Ulysses (International Solar Polar Mission). This ESA satellite, the first spacecraft to leave the ecliptic plane of the solar system, will study the interplanetary medium and solar wind from a completely new perspective — over the two poles of the Sun. Experiments will study the heliospheric magnetic field, solar radio bursts and plasma waves, solar x-rays, and the structure of the Sun/wind interface, all as they relate to changes in solar latitude. Instruments are provided by both European and American investigators.

Ulysses will achieve this unique vantage point with the aid of a gravity-assist trajectory around Jupiter. Launched from the Space Shuttle, the spacecraft will use a Centaur upper-stage motor to reach Jupiter fourteen months after launch. About two years after passing Jupiter, Ulysses will pass over the pole of the Sun, then the craft will recross the ecliptic plane and pass over the opposite pole of the Sun about five years after launch.

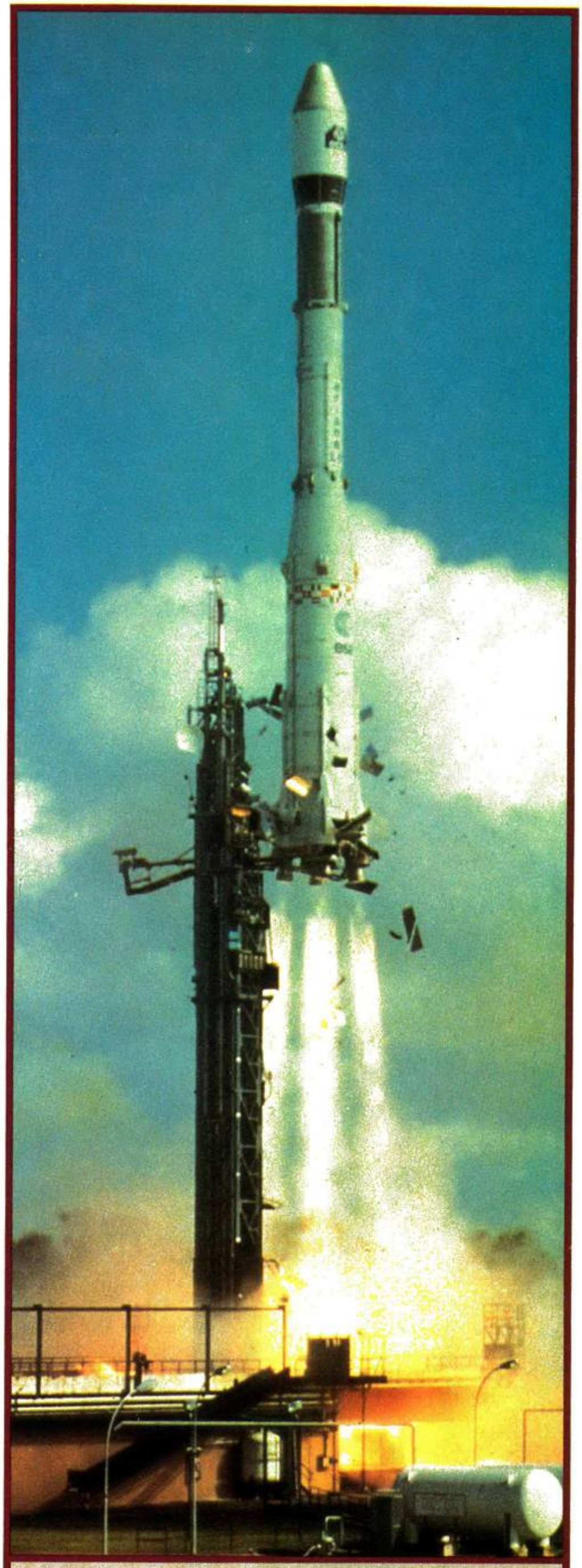
The project is a joint venture of NASA and ESA; the spacecraft was created by ESA and the launch and mission communications support will be provided by NASA. Originally, two spacecraft were to be used in the Solar Polar Mission, but the second, to be built by the United States, was canceled due to budget cuts.

[The launch, originally scheduled for May 1986, has been postponed as a result of the Space Shuttle Challenger explosion in January. The next launch opportunity that would bring Ulysses to Jupiter is in the summer of 1987.]

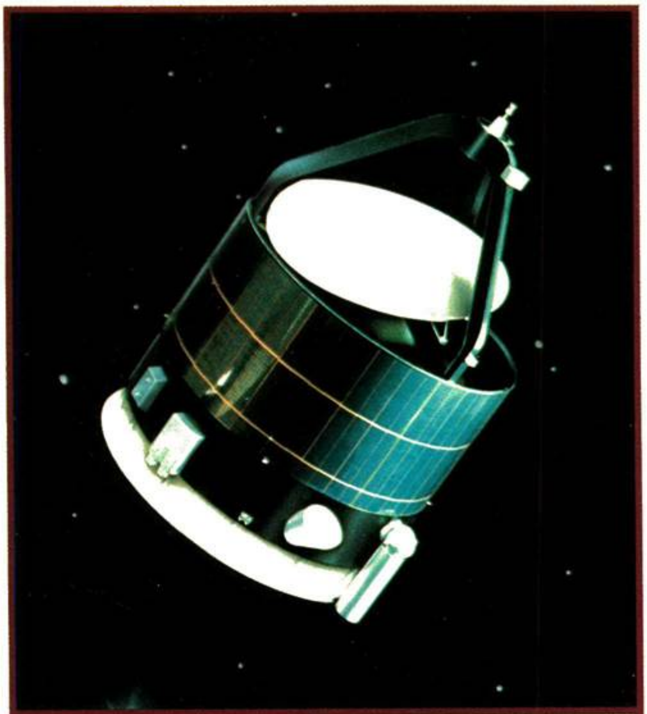
International Sun-Earth Explorer (ISEE). Three ISEE satellites were launched to study the dynamic properties of the magnetosphere. ISEE-1 and 3 were built by NASA and ISEE-2 by ESA. ISEE-1 and 2 were launched together in 1977 and work as a team. They circulate through the magnetosphere making identical observations. Comparisons of the data they acquire allows for measurements of the speed and direction of plasma and radiation.

The third spacecraft, ISEE-3, was launched in 1978 and was originally positioned between the Earth and the Sun. Its task was to monitor the solar wind before it encountered Earth's magnetosphere. In March 1983, maneuvers were begun to send the spacecraft to an encounter with Comet Giacobini-Zinner. Renamed the International Cometary Explorer (ICE), it reached the comet in September 1985 and earned the distinction of being the first spacecraft to intercept a comet. (See "ICE: Mission to Comet Giacobini-Zinner," December 1985.)

Hubble Space Telescope. ESA is participating in the Hubble Space Telescope project with NASA. The Space Telescope will extend the sensitivity, resolving power, and spectral range of astronomical observations far beyond those obtainable with



Getting into space has been the job of the expanding family of Ariane launchers since 1981.



Comet Halley was the destination of the recently completed Giotto mission, the first to directly encounter a comet.

Earth-based telescopes. It is expected to view objects that are up to ten times fainter than can be observed from the ground.

The main European contribution to this program is the Faint Object Camera, which will enable the telescope to photograph objects down to 29th magnitude and study faint structures around bright objects. ESA has also built the solar arrays that supply power to the Space Telescope.

Exosat. This is an entirely European x-ray observatory satellite, which was launched into Earth orbit in 1983. Exosat has studied the x-ray emissions from normal stars like our Sun, cataclysmic variable stars (binary systems containing a white dwarf), neutron stars, supernovae remnants, and active galactic cores. The satellite carries four instruments: two imaging telescopes, a large area proportional counting array, and a gas scintillation spectrometer. Exosat can determine the exact location of x-ray sources, and map diffuse and extended sources with the imaging telescopes.

The satellite has exceeded its two-year life expectancy and is expected to operate through 1986.

Hipparcos. The space-astronomy mission of Hipparcos will provide measurements of the positions, annual proper motions, and parallaxes of some 100,000 pre-selected stars. For two-and-one-half years it will scan the entire sky to produce a reference system of unprecedented accuracy. Launch is scheduled for mid-1988 aboard an Ariane booster.

An Independent Launch Capability

Ariane is the pride of all European space buffs — positive proof that Europe can equal the space powers that have monopolized satellite launching up to now. With a growing family of increasingly powerful launchers and a recently expanded launch facility, the Ariane system will be putting more and more satellites into orbit in the years to come.

Ariane is a three-stage, heavy-satellite launcher designed for a wide variety of missions that range from hoisting low-orbit payloads into space to exploring deep space. However, the launcher is best suited and most often used to place commercial satellites in a geostationary orbit some 35,800 kilometers above Earth.

Unlike the Space Shuttle, Ariane is based on the proven technology of conventional rocketry. Its first and second stages use engines that had already reached a high state of development. The third stage, however, uses cryogenic (super-cooled) propellants — liquid hydrogen and oxygen — as do the main engines of the Space Shuttle.

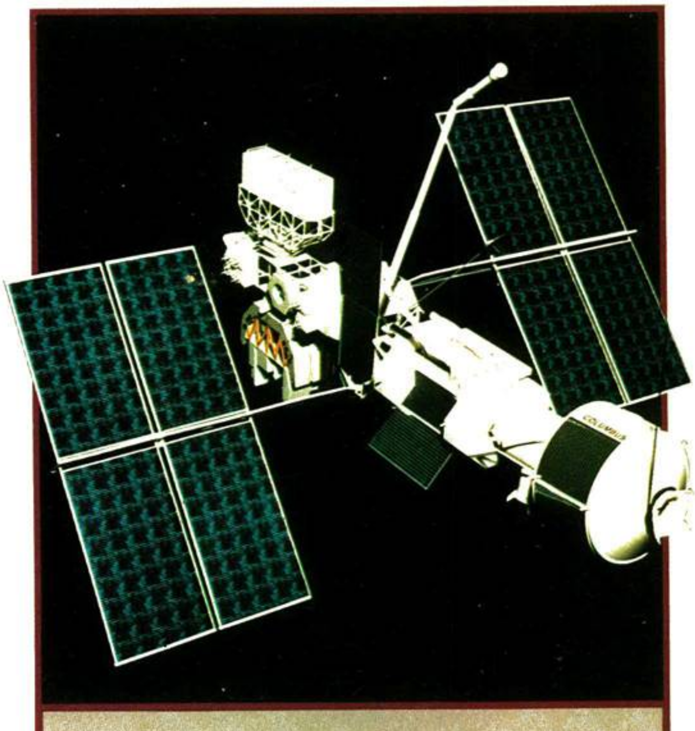
The development of the Ariane launcher was begun by the European Space Research Organization (ESRO) in July 1973. The member states of ESRO decided to develop a booster that would give Europe an independent launching capability for its own communications and scientific satellites, and that would allow Europe to capture a share of the world market forecasted for launching commercial satellites.

Like the Space Shuttle, Ariane underwent a series of four test flights — and it beat the Shuttle into space. The maiden launch occurred in December 1979 and the first payloads were put into orbit in June 1981. Through 1984, Ariane completed eleven flights with the final two employing the Ariane 3 version of the booster. The Ariane 3 uses two strap-on solid boosters, which give the launcher an overall payload capacity to geosynchronous transfer orbit (a midpoint toward geostationary orbit beyond which a satellite uses its own engines) of 5,687 pounds.

The Ariane 4, an even more advanced model, should be ready for launch in August 1986. This type of launcher uses a standard core rocket with different combinations of strap-on boosters. The most powerful and largest version, the Ariane 44L, will be able to lift a payload weighing 9,240 pounds into geostationary orbit.

The Ariane launcher, like its counterpart the Space Shuttle, has had its problems. In its six years of operation, Ariane has had three launch failures. The most recent occurred on September 12, 1985, when the third-stage motor failed, destroying Ariane 3 and its payload of two satellites.

Ariane is launched from the Guiana Space Center near the city of Kourou in the South American country of French Guiana. The site is located on 386 square miles of savannah stretching along the Atlantic coast. A launch facility so close to the equator



A permanent place in space is the long-term goal of the Columbus space station project.

takes full advantage of the extra velocity imparted to an eastward-launched rocket by the Earth's rotation. An Ariane booster launched from Kourou (5° north latitude) can lift 17% more payload than a similar booster launched from Kennedy Space Center in Florida (28° north latitude).

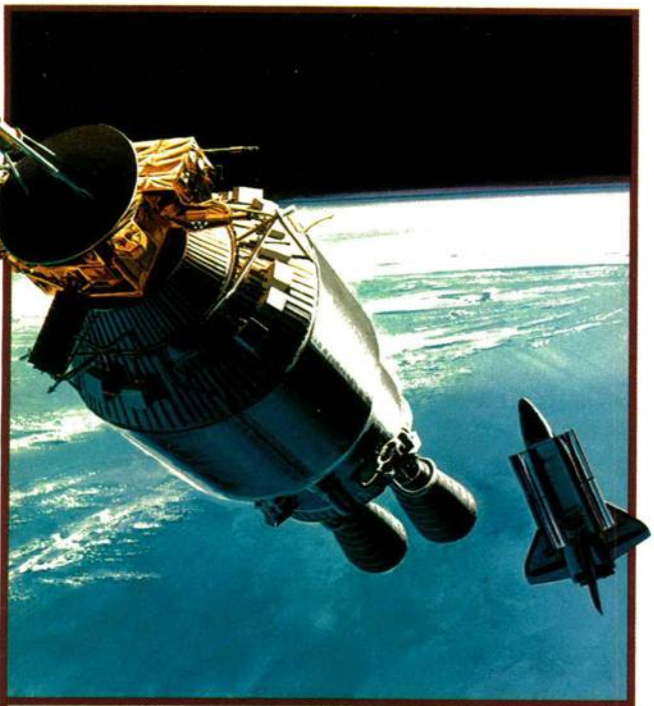
The Guiana Space Center now has two operational launch pads that will be able to handle as many as ten Ariane launches each year. Built by ESA, these launch facilities, like the Ariane rockets that launch from them, are managed not by ESA but by a private company called Arianespace.

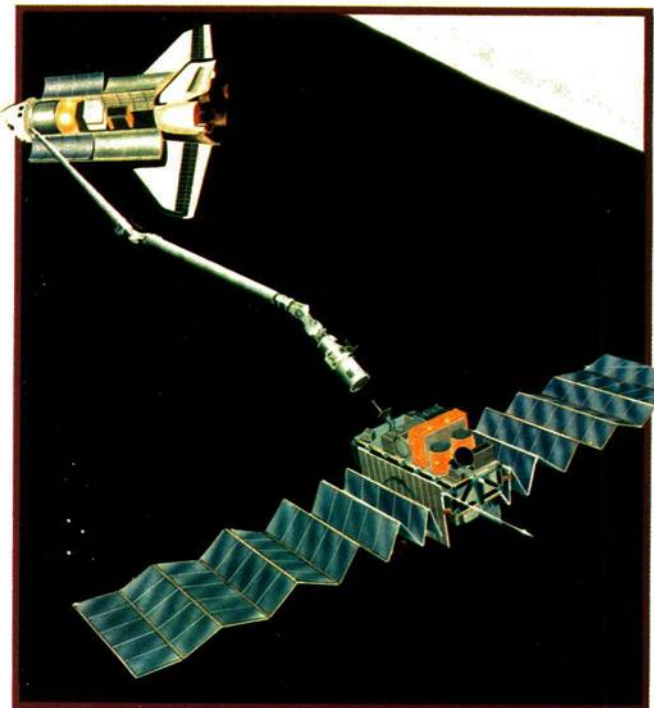
ESA decided at the onset of the Ariane program that it would separate the development aspects of the program from the production and operation functions. In March 1980, three months after the first Ariane launch, Arianespace was formed to manage and market the Ariane system as a commercial enterprise.

To date, 40% of Arianespace's orders have come from outside of Europe. Competing directly with the Space Shuttle for commercial payloads, Arianespace has gained this measure of success through aggressive marketing. Ironically, the European launcher is marketed through Arianespace, a *private* firm, and the Shuttle is marketed through NASA, a *government* agency.

The success of this type of private management of a space transportation system was recognized in a 1982 report by the U.S. Office of Technology Assessment: "Arianespace is offering customers highly attractive terms, including below-market financing through European banks, and an extended period in which to make repayment. For these reasons, the Ariane is likely to have a full manifest for the foreseeable future, despite the superior capabilities of the Shuttle."

What does the future hold in store for Ariane? In January 1985, ESA gave the go ahead for development of the Ariane 5 heavy-lift launcher. France has developed six versions of the Ariane 5, each offering different configurations of the upper stage. One, two, or three spacecraft could be launched by a single rocket depending on their weight. One configuration would allow for launch of a proposed manned vehicle called Hermes. The Ariane 5 could put up to 17,000 pounds of payload into geo orbit and 33,000 pounds into low-Earth orbit. Production of the Ariane 5 is expected to begin next year with the first launch scheduled for 1995.


A new angle on solar research will be obtained when Ulysses flies over the poles of the Sun.


Space experiments will be able to stay in orbit for up to six months aboard the Eureca retrievable platform.

The expanding Ariane family has enabled Europe to launch its own applications and scientific satellites and to capture an important share of the estimated 200 geostationary satellites to be launched during this decade. But aside from its commercial benefits, Ariane carries Europe's hope for a strong and independent position in space.

Europe's First Step Into Space

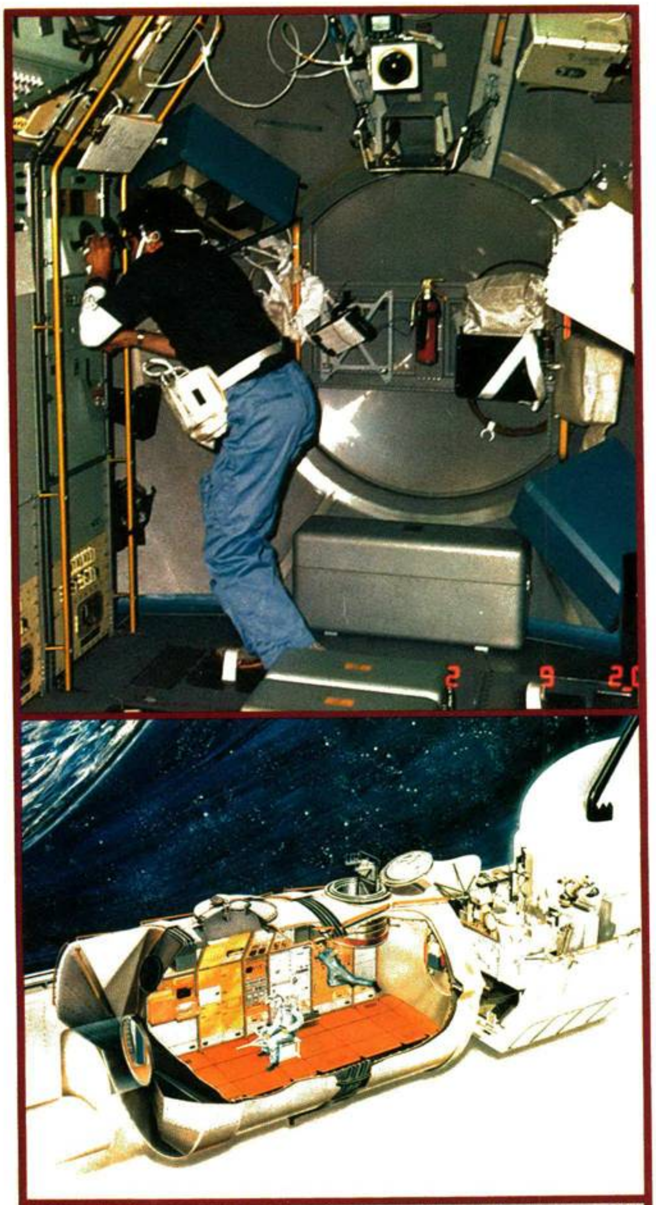
The European space effort is perhaps best known for Spacelab, the manned laboratory that ESA developed to fly as part of the Space Shuttle. The experiments conducted aboard Spacelab have resulted in an expertise in areas that will be invaluable in the future development of permanently manned space stations.

The origins of Spacelab start back in the year of the Moon, 1969. The United States invited Europe to participate in the post-Apollo space program, which was then just being planned. After the U.S. approved development of the Space Shuttle in 1972, several elements for the system were studied as candidates for European involvement. These included building parts of the actual Space Shuttle or building a space "tug" to be used in cooperation with the basic Shuttle system.

One idea, however, stood out as most suitable for European development: a "sortie can," as it was called. This was a cylindrical, pressurized compartment that would be mounted in the cargo bay of the Shuttle and connected to the orbiter's electrical and air systems. It would provide laboratory space for science missions lasting a week or more.

At the ministerial meeting of the European Space Conference in 1972, the sortie can, then renamed Spacelab, was approved as a special project by ESRO. The design concept was chosen in August 1973 after preliminary design studies. A Memorandum of Understanding was initialed in Paris that month between NASA and ESRO.

The Spacelab that finally evolved out of the 1970s is not one lab but a set of interchangeable segments that can be tailored



[illegible] has allowed man to study both [illegible] universe from the vantage [illegible]

to particular missions. The central component of this "tinker toy" set of modules is the habitable laboratory module, which comes in two versions. The short module consists of a single cylindrical segment 8.8 feet long and 13.25 feet in diameter. This core segment contains essential subsystems for running the Spacelab's air, cooling, computer controls, and so on.

This module also provides room for standard-sized racks of scientific equipment. The racks come in two sizes, a 22-inch-wide single rack and a 41-inch-wide double rack. The single rack can carry up to 639 pounds of equipment and the double rack can carry up to 1,278 pounds. The short module holds a pair of each type of rack. A workbench occupies the same space as a double rack. Items can be secured to the table-like surface with elastic cords hooked into holes in the bench. The workbench contains six drawers, filing cabinets, and four storage compartments.

The long module grafts another 8.8-foot segment to the laboratory. This module can accommodate four double racks and two single racks devoted exclusively to additional experiments.

Overhead space in these modules is used for storage and for direct and indirect access to space for experiments. A circular hatch-like section can be fitted with two types of windows for visual and photographic experiments or with an airlock for placing experiments directly into space.

Instrument-carrying pallets can be flown with the manned modules to carry telescopes, cameras, and sensing devices that are directly exposed to space in the Shuttle bay. Three to five pallets measuring 10 feet long by 13 feet wide can be flown at once.

The first Spacelab mission was in orbit for ten days during November/December 1983 aboard Shuttle mission STS-9. Aboard were John Young, Brewster Shaw, Owen Garriot, Robert Parker, Byron Lichtenberg, and Ulf Merbold. Merbold, ESA's representative on Spacelab 1, became the first non-American to fly on a U.S. spacecraft. The mission was a joint NASA/ESA flight, with ESA riding the Shuttle for "free" as a reward for developing the lab.

The first flight was an overall evaluation of the Spacelab system, consisting of the long module and one pallet. Special sensing equipment monitored the engineering performance of the system. The mission was packed with 70 experiments to check Spacelab's science capabilities in a wide range of areas. The experiments, from eleven European countries plus the U.S. and Japan, were conducted in the areas of astronomy, physics, Earth observation, materials science, life sciences, and technology demonstration.

Three subsequent Spacelab missions have been flown to date. Spacelab 3 (which flew before Spacelab 2 because of technical problems) had no direct involvement with ESA when it flew in April/May 1985. The Spacelab 2 flight in July/August 1985, the final verification flight for the system, consisted of a pallets-only configuration of modules. The most recent flight in October/November 1985, Spacelab D1, was completely managed by a crew from West Germany.

Spacelab 2 carried thirteen experiments, most of which were conducted with instruments directly exposed to space in the Shuttle bay. The system's support equipment controlling these experiments, which are normally housed in the manned module, was contained in an unmanned "igloo" cylinder in the bay. Experiments were controlled by astronauts inside the Shuttle. Among the scientific data produced by Spacelab 2 were detailed images of the Sun and observations of galactic x-ray sources.

This mission was the first flight of the Instrument Pointing System (IPS) that ESA developed as part of the Spacelab system. IPS provides precision pointing capabilities for telescopes and other instruments that require better accuracy and stability than can be obtained from instruments mounted in the orbiter. IPS broadens the range of experiments that can now be performed on the Shuttle.

The Spacelab D1 mission gave the European space establishment direct experience in managing manned flight. Marking the first time that control of a Space Shuttle payload occurred outside the United States, Spacelab D1's "mission control" was at the Payload Operations Control Center near Munich, West Germany.

Working in two shifts, the crew conducted experiments from European and U.S. investigators. An area of continuing European interest — microgravity — was the focus of many experiments. Life sciences experiments studied the effects of weightlessness and cosmic radiation on living organisms. Materials science experiments studied the behavior of fluids, crystal growth, and metallurgy. Results from this mission are due in August 1986.

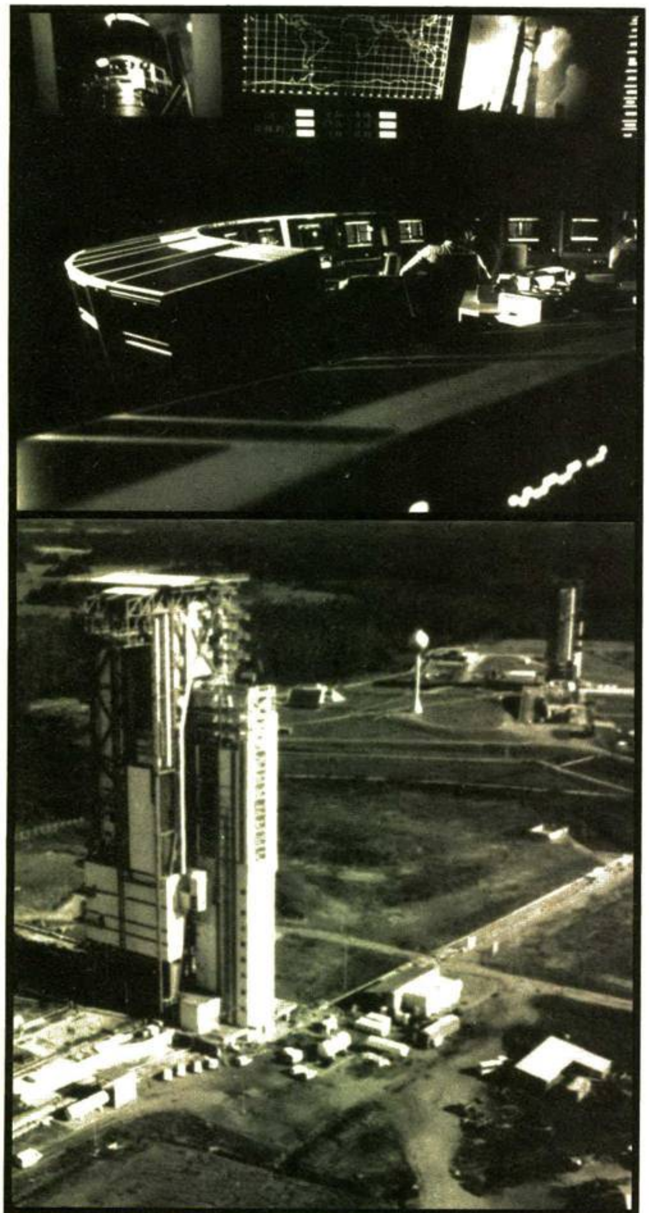
Developed by ESA at a price of $920 million, Spacelab now belongs to NASA and ESA must pay for any future use of the hardware that it developed. Some Europeans argue that ESA should have received more than one-half of the first flight in return for having developed, designed, and financed the building of the project. They call the Spacelab deal a "steal" by NASA. Even Ulf Merbold is reported to have grumbled a bit after the flight, saying that Europeans should get more use of their "gift" to the United States.

But Europeans have already received real value for the money they spent. Spacelab gave ESA and European industry experience in designing and manufacturing equipment that will be put to use in a variety of future projects leading up to a manned space station.

Toward a Space Station

ESA is currently cooperating with NASA in the development of the Space Station (see Astro News, March 1986). The European role in the project will likely involve work on the manned modules and the experiment-carrying platforms attached to and flying free around the station.

Planning has already begun on a new ESA project that will advance European expertise in unmanned platforms. Eureca (European Retrievable Carrier) will be an unmanned platform carried aloft by the Shuttle to an altitude of 300 kilometers. From there, the platform will use its own propulsion system to reach its operational altitude of 500 kilometers. When its mission is completed, the craft will fire its engines to return to lower orbit for retrieval by the Shuttle.



"Mission Control" in West Germany (top) and the Guiana Space Center are major European space facilities.

Weighing a total of four tons, Eureca will be able to carry 2,645 pounds of payload. The first Eureca flight, expected to be ready for launch by March 1988, will carry experiments in the microgravity sciences (life and material sciences), propulsion, and communications. Eureca offers the advantages of relatively long flight duration — six months or more — without the disturbances produced by a manned crew or spacecraft. This will be a boon to astrophysics experiments that demand longer observation times than those offered by the Shuttle.

The Eureca concept of a free-flying platform could easily develop as Europe's contribution to NASA's Space Station. With suitable docking techniques, the platform could be serviced by the manned station as a semi-permanent payload carrier. Joint use of the Eureca platform by ESA and NASA is currently under consideration.

Eureca could also evolve into an experiment-carrying segment for a proposed European space station named Columbus. Columbus will either develop into a totally independent space station or become part of the European contribution to the NASA project. It presently looks like Europe will first cooperate with the U.S. and thereafter build an independent space station.

Columbus will consist of at least one manned module (based on the Spacelab design) plus an open platform (derived from Eureca) and a resource module. In its simplest form, Columbus would consist of a two- or three-segment module docked to the Space Station for its power supply.

West Germany recently proposed that the manned laboratory module be made capable of independent operation detached from the Space Station. Such a free-flying module would serve as a "quiet laboratory" for sensitive microgravity experiments. This concept is being considered by ESA and its member states.

The addition of a resource module, solar arrays to provide power, environmental controls, and communications would transform the manned module into a fully independent space station. Additional elements could be launched by advanced Ariane boosters. The system would be "man-tended" at first with periodic visits from crews, then grow into a permanently occupied facility with "shift-crews" arriving and departing on the Hermes mini-shuttle.

Hermes is envisioned as a 50- to 60-foot-long spaceplane with a wingspan of 32 feet. It would carry a crew of four plus a small payload of about five tons. The craft could stay in space for ten days on its own or ninety days if docked to a space station.

As this look at Europe's future plans illustrates, the various elements of the European space program may come together into a unified and wide-ranging manned space system around the year 2000. Spacelab stands as a symbol of this promising and vigorous effort. It symbolizes Europe's serious desire to actively engage in the forefront of scientific space-based research.

Spacelab can also be seen as representing Europe's positive attitude toward increasing cooperation with other space nations while at the same time developing the means for autonomous activity. It characterizes ESA's present attitude toward the future: on one side a cooperation with NASA in building the Space Station, and on the other side, the acquisition of technical and scientific *savoir-faire* that will allow Europe to develop the no longer utopian dream of an independent European manned space program. We already have the "Euronauts," we only have to find occupations for them!

Europe has already taken its first steps toward space. Indeed, we already have twenty years of space experience behind us. And there is no indication that Europe is slowing down in this field. ESA is currently considering proposals for missions to study the volcanic atmosphere of Jupiter's moon Io, the internal structure of Mercury, and the planet Venus. The world is slowly realizing that Europe must be dealt with as a genuine "space power" in scientific, technical, and commercial areas.

Philippe Van Nedervelde is general manager of the Belgian Space Information Center.

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Following Halley Out

Remember when Halley's current apparition seemed like nothing more than a far-off thought, something that might not really happen? That wasn't long ago. And now our time for seeing the comet is nearly over — Halley is once again on its way out.

Relatively speaking, this well-documented, 29th return of Halley's Comet wasn't a very good one, especially for Northern Hemisphere observers. When Halley shone at its brightest during March and April its nucleus typically rose only a few degrees above the horizon for mid-northern skywatchers. How could our generation — the first capable of examining Halley with sophisticated photographic emulsions and CCD chips — be so cheated by history?

In spite of the fact that Halley's Comet was surpassed in splendor by many other comets since its last visit, most people were satisfied merely by getting a glimpse of the faint, mysterious snowball. Thankfully the view in May will be less obscured by the horizon for Northern Hemisphere observers — although Halley will rapidly become fainter — as the comet swings up through a graceful northeastward arc in the constellation Sextans and fades from view until the year 2061.

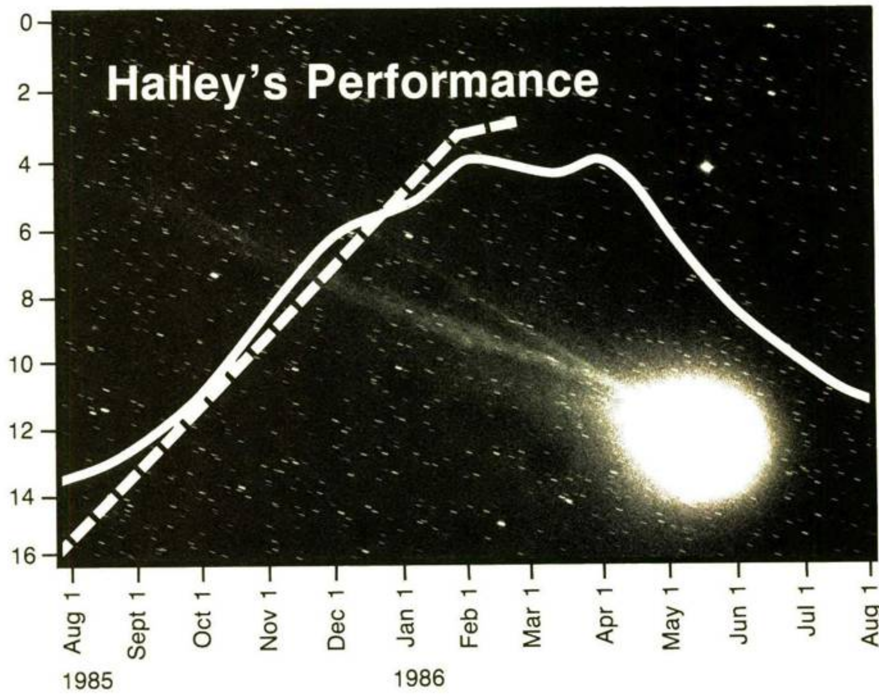


Chart: David J. Eicher; photo: European Southern Observatory

Magnitude predictions made by the International Halley Watch suggested that Halley would peak at 4th magnitude in February and April 1986 (solid line). But photometry and visual estimates from many observers (dotted line) show that during the first half of Halley's apparition, the comet surpassed the IHW prediction by late December 1985 and grew brighter than 4th magnitude at the end of January 1986.

Bidding Halley Farewell

As the Moon wanes to Last Quarter during the last few days of April, Halley is again visible low in the southeastern sky. By now it lies in northern Hydra, bound for Crater the Cup — a faint constellation whose brightest star glows dimly at 4th magnitude. On the night of April 24/25 (the evening of the 24th and morning of the 25th) the Moon is full and will interfere with comet viewing. But by the evening of April 26/27, twilight ends by mid-evening (9 p.m. local time at 42° north latitude), the comet transits half an hour later, and the Moon doesn't rise until an hour after that. This combination of events allows you to search for the comet unhampered by scattered sunlight.

During these last days of April, Halley — whose brightness has proved difficult to predict with certainty — should shine between magnitudes 4.5 and 5.5 and may still be showing a small tail. The blessing for Northern Hemisphere observers is that the comet will be moving rapidly northward until mid-May, when its apparent motion will slow considerably. This northward path will carry the comet high enough in the sky to be conveniently viewed again from northern latitudes. It will lie in a relatively barren region of sky far from the plane of the star-rich Milky Way, and will cross into the constellation Crater by the morning of the 25th.

Because of a lack of bright stars in Halley's immediate area, the comet will not be too easy to find. Careful "star hopping" from an easily identified star in the same general region of sky will be required.

Star hopping is a technique as old as telescopes. It requires no equatorial drive or setting circles, simply a reliable finder telescope and a good sky map (see pages 92-93). The only skills necessary are identifying a bright star in the same part of the sky as the object you wish to find, pointing the finder telescope at it, and slowly and carefully hopping over to the target area using successively fainter star patterns.

Since there are no star labels, constellation lines, or coordinate grids in the sky, to star hop you must be able to recognize patterns of stars. Thankfully there are enough distinctive triangles, pairs, and odd shapes formed by stars (even in a rather barren area of sky) that one pattern won't be confused with another.

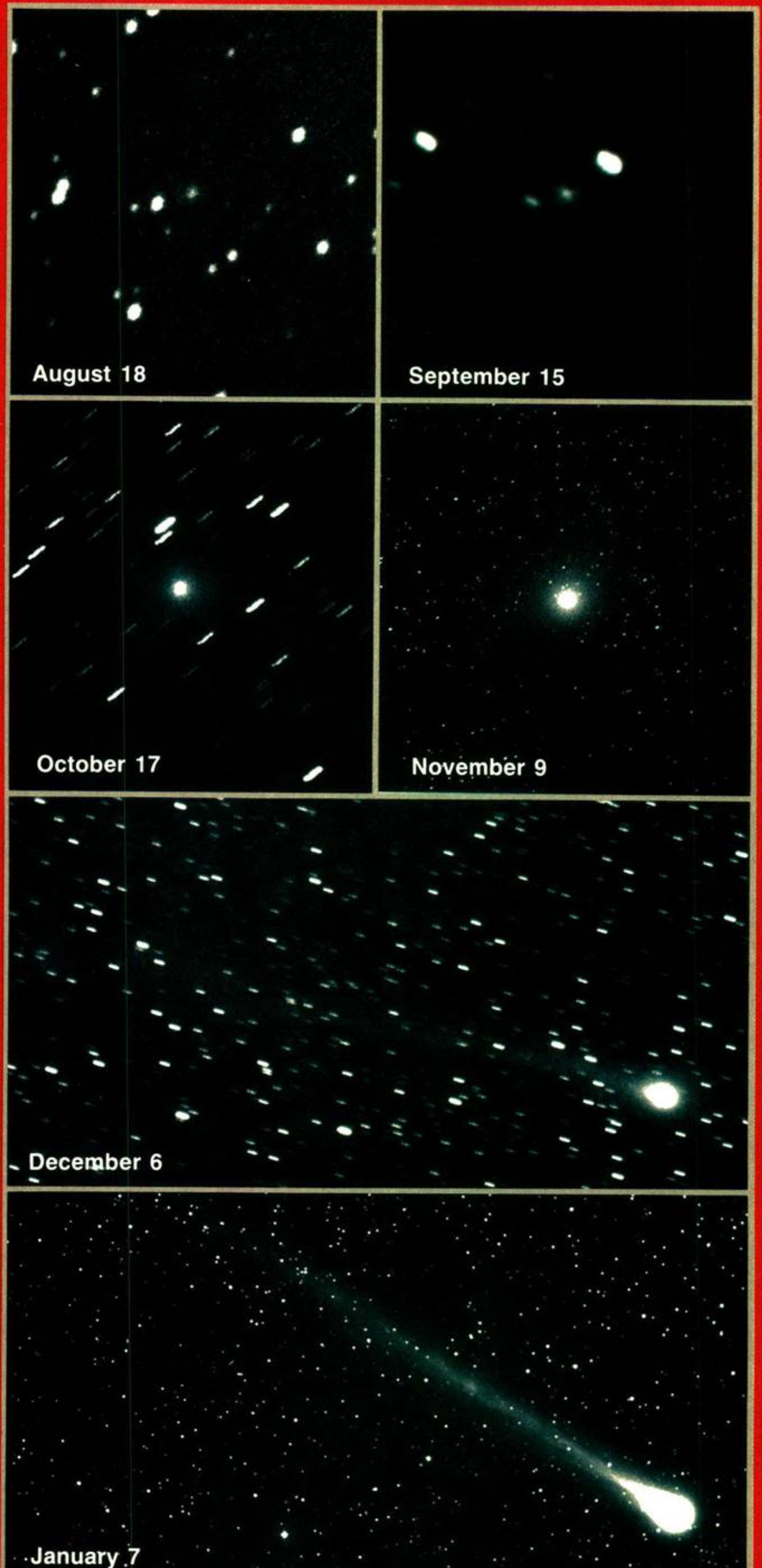
Suppose you want to observe Halley on the evening of April 30/May 1. Take your telescope out early so that it can acclimatize to the air temperature, and then return inside to study the map showing Halley's position. You'll see that on this evening Halley's nucleus lies just 1° southwest of the yellowish 4.1-magnitude star Alpha Crateris (α Crt). How do you identify this rather ordinary star floating in a sky devoid of notable guideposts?

Start by locating Spica (Alpha [α] Virginis), the bluish beacon that is the brightest star in the southeastern sky. (To positively identify this area and its surroundings, see the star map in the center of this issue.) Spica gleams at an unmistakable 1st magnitude and is the perfect jumping-off point to hop your way over to α Crt.

Once you've located Spica, look 15° southwest (the width of an extended fist approximates 5°) and you'll find a group of six 3rd- and 4th-magnitude stars arranged in the trapezoid-shaped constellation called Corvus the Crow. The pair of stars at the northeastern corner of this bent square is composed of Delta (δ) and Eta (η) Corvi; the northwestern corner is marked by Gamma (γ) Corvi. Beginning with the bright pair, move your telescope through Gamma and continue due east for an equal distance. You'll come to a wide pair of fainter stars in Crater, the 5th-magnitude suns Eta and Zeta (ζ) Crateris. Moving your telescope 5° eastward from Zeta will bring you to the wide bright pair of stars Gamma and Lambda (λ) Crateris. Continuing another 5° to the east will set the finderscope upon its destination, α Crt.

Once you find α Crt, take a good long look at the surrounding stars since they'll be used to locate Halley during the next

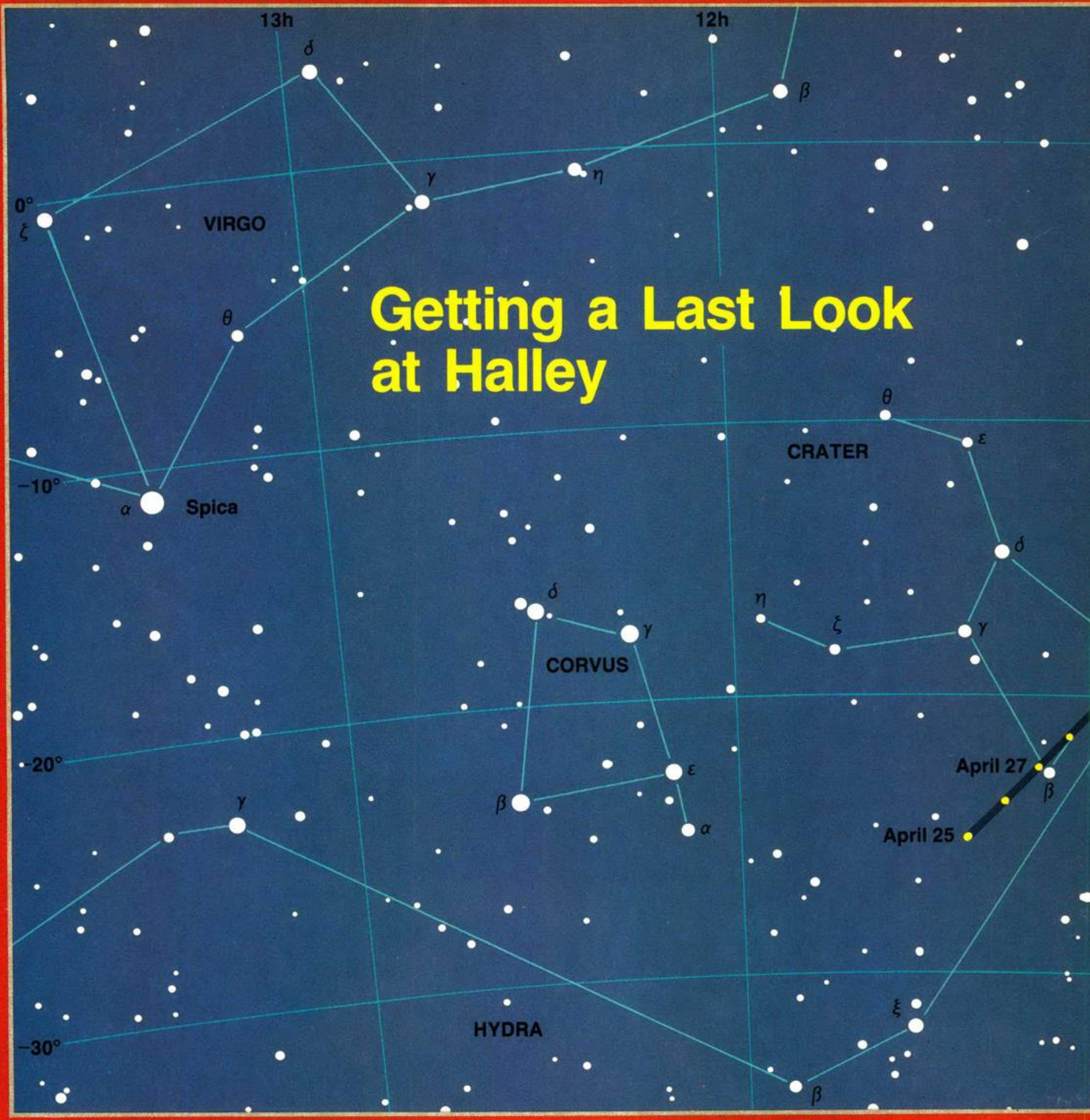
Watching Halley Grow



Watching Halley Grow

This series illustrates the comet's rapid growth in size and brightness as it approached the Sun. *August 18*: Halley was a starlike dot of light meekly glowing at fainter than 14th magnitude. Photo by Bill Hall. *September 15*: The comet became visible in large backyard telescopes as a faint "galaxy." Photo by John Stull/Alfred University Observatory. *October 17*: During October, the comet brightened enough to be seen by thousands of skywatchers and grew large enough to easily identify as a nebulous ball of light. Photo by John Stull/Alfred University Observatory. *November 9*: November saw Halley pass the Pleiades cluster in Taurus (temporarily making it very easy to find) and develop minute signs of a tail. Photo by Al Ernst. *December 6*: With a tail stretching 3° long under a dark sky, Halley became a respectable comet during December 1985. Photo by Alfred Lilge. *January 7*: Before sinking into February's evening twilight, Halley's Comet was a 4th-magnitude glow sporting a 5°-long tail. Photo by David Healy.

Getting a Last Look at Halley



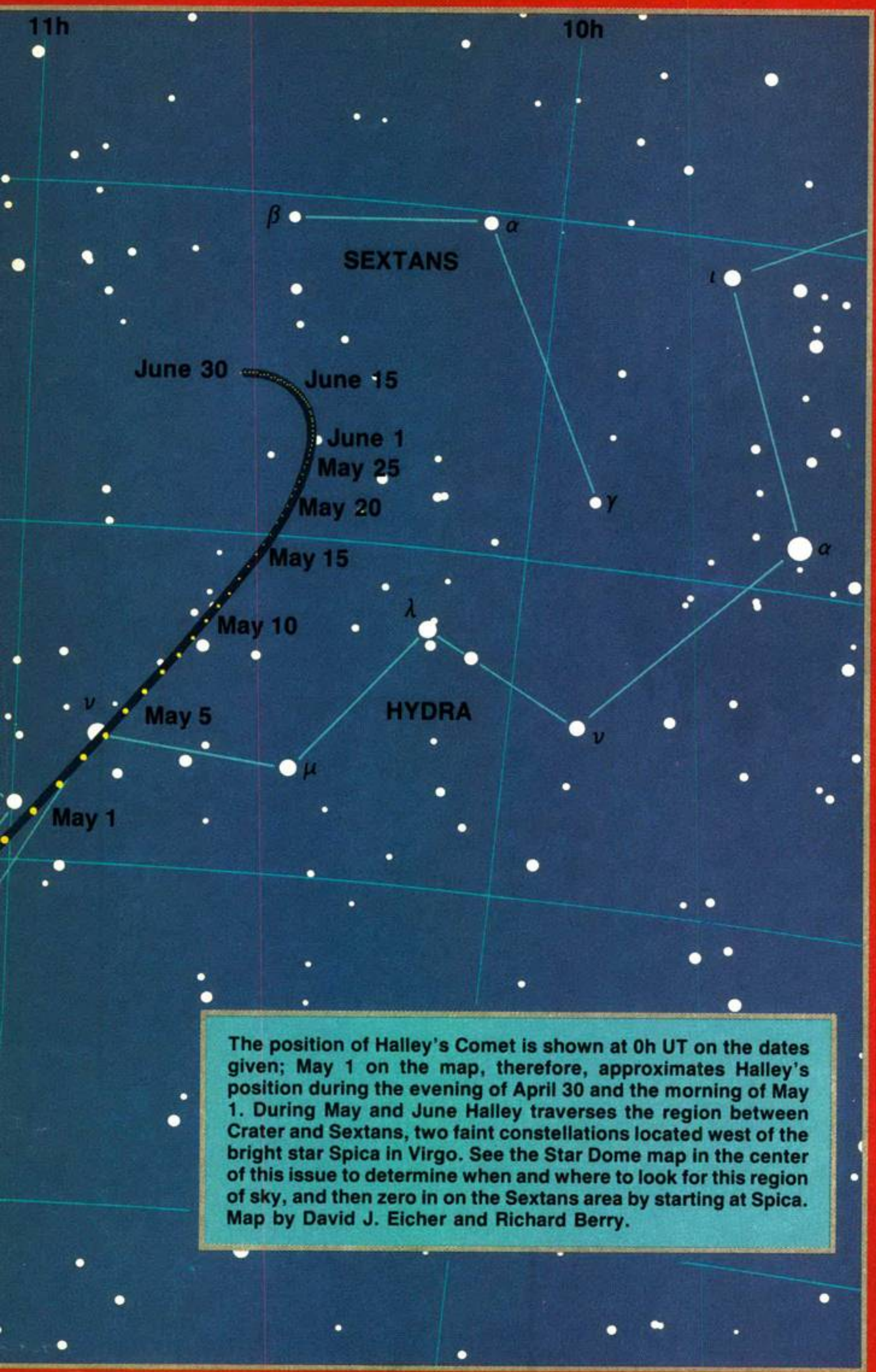
two months. Then place the finderscope back on α Crt.

What to Expect in May

On the evening of April 30/May 1, finding Halley by star hopping from α Crt will be foolproof. But before observing the comet, fit your telescope with a low-power eyepiece, make sure your eyes are well-adjusted to the dark, and have a red-filtered flashlight handy for checking the star map so you don't damage your dark adaptation. When you're set to go, move the scope about 1° southwest of α Crt; Halley, appearing as a 5th-magnitude roundish cotton ball of nebulosity, will be centered in the eyepiece.

Cherish the view of Halley while you can. At the beginning of May, the comet will be 150 million miles from Sol and 75 million miles from Earth. As it swiftly moves away from both, its magnitude will dwindle for two reasons. First, the comet's intrinsic brightness will fall off rapidly as it recedes from the Sun and begins cooling off into a solid, frozen mass. Working in cooperation with this true dimming is the comet's motion away from Earth, which causes a further decrease in brightness. So observe Halley as early in May as possible, for the comet will be fading with every tick of the clock.

By the evening of May 4/5, the comet will have moved into the constellation Hydra the Water Serpent, a long, gangly collection of relatively faint stars spread over one-quarter of the celestial sphere. Halley will then lie some 157 million miles from the Sun and 86 million miles from Earth; it will likely have faded to about 6th magnitude. Finding the comet on this evening will be convenient since it lies roughly 1.5° northwest of the



The position of Halley's Comet is shown at 0h UT on the dates given; May 1 on the map, therefore, approximates Halley's position during the evening of April 30 and the morning of May 1. During May and June Halley traverses the region between Crater and Sextans, two faint constellations located west of the bright star Spica in Virgo. See the Star Dome map in the center of this issue to determine when and where to look for this region of sky, and then zero in on the Sextans area by starting at Spica. Map by David J. Eicher and Richard Berry.

3rd-magnitude yellowish star Nu Hydrae (ν Hya).

As you continue to watch Halley, take critical note of its appearance. Is the comet perfectly round? Is its coma uniformly lit or is the center brighter than the rest? Is there a tail and if so how long is it? Careful observation of the comet with a range of eyepieces and unhurried stares will improve your skill as a skywatcher.

May's first Moon-free window for Halley observing lasts until about May 16 when the Moon returns to the evening sky. This long period with Halley in the evening sky should provide you with ample opportunities to see the comet, despite the Northern Hemisphere's characteristically damp spring season. On the evening of May 9/10, Halley is some 164 million miles from the Sun and 100 million miles from Earth, causing the comet to shine between magnitudes 6 and 7. The coma should be noticeably smaller than it was two weeks earlier, and your visual impression may be, "Oh my gosh, Halley is shrinking fast before my eyes!" The comet will lie just a degree northeast of the variable star U Hydrae and a degree south of a clump of 6th-magnitude stars some 5° northwest of ν Hya (see map).

By the evening of May 15/16, the night before the waxing Moon reaches First Quarter, Halley will lie a degree west of a solitary 6th-magnitude star. On that date the comet will lie 171 million miles from the Sun and 115 million miles from Earth, resulting in an appearance like that of a 7th-magnitude elliptical galaxy: a fuzzy, featureless spot of light.

. . . And On Into June

The Moon interferes with viewing Halley until about the evening of May 24/25, two nights after Full Moon. By this time the comet lies in the faint constellation Sextans and begins its northeastern arc. Its motion across the sky slows to less than a degree per day. The Sun and Earth distances are much greater than they were early in May — some 184 and 146 million miles, respectively — and Halley becomes a faint object as viewed with small telescopes.

The sky is now different during the evening as well, with Sextans lying in the south*western* sky after dark. The time available for viewing Halley's Comet is dwindling.

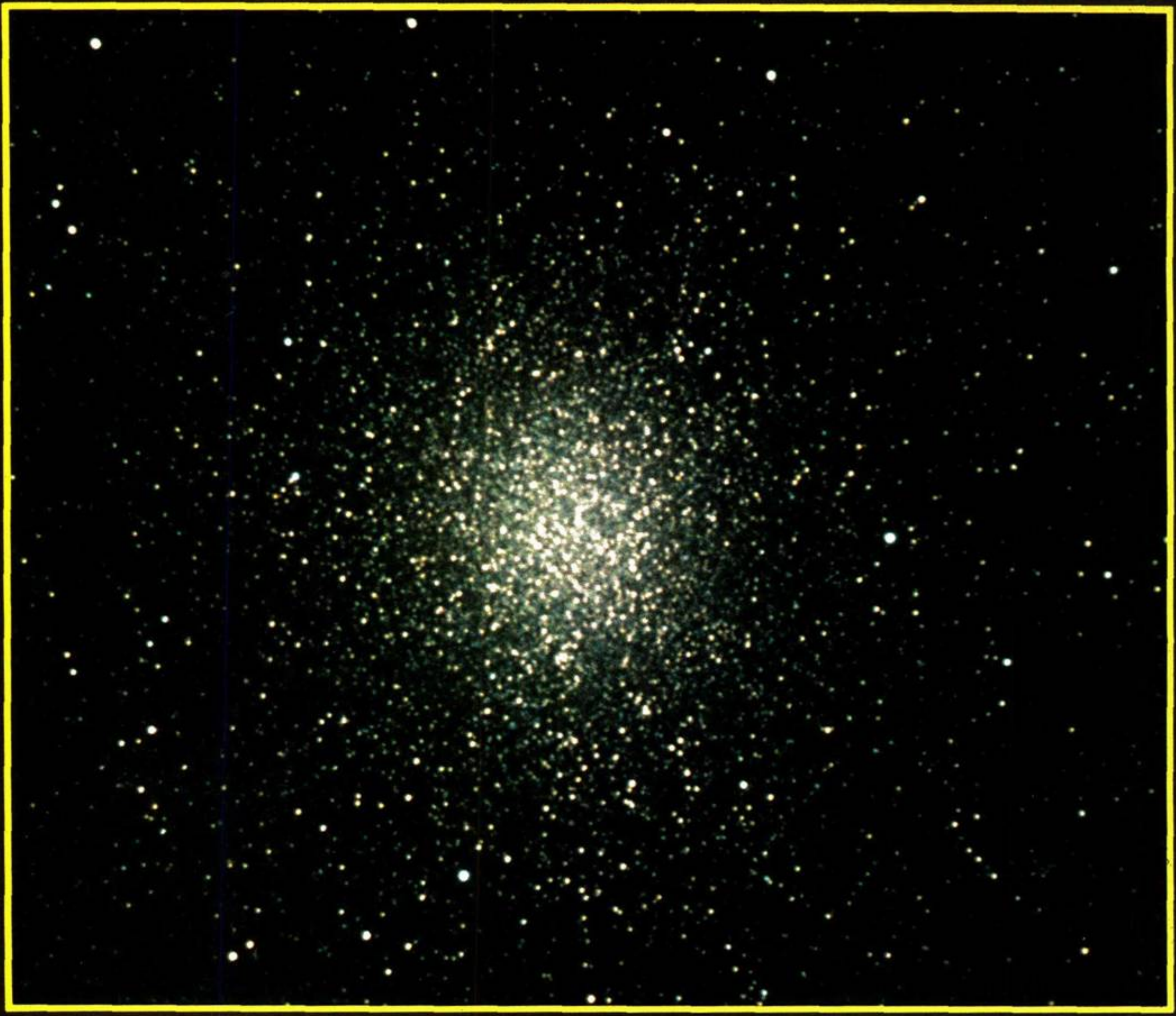
On the evening of May 24/25, the comet lies some 2.5° east of the 5th-magnitude, pure-white star Epsilon Sextantis (ε Sex). Halley should appear as an 8th-magnitude, smallish blob something akin to the brightest galaxies in the Virgo cluster. As a comparison, move away from Halley by swinging your telescope's field of view 3° west of ε Sex; provided you're using a low-power eyepiece, you'll see the 9th-magnitude spindle-shaped galaxy NGC-3115. Is Halley brighter or fainter than this nebular object? Is it larger or smaller?

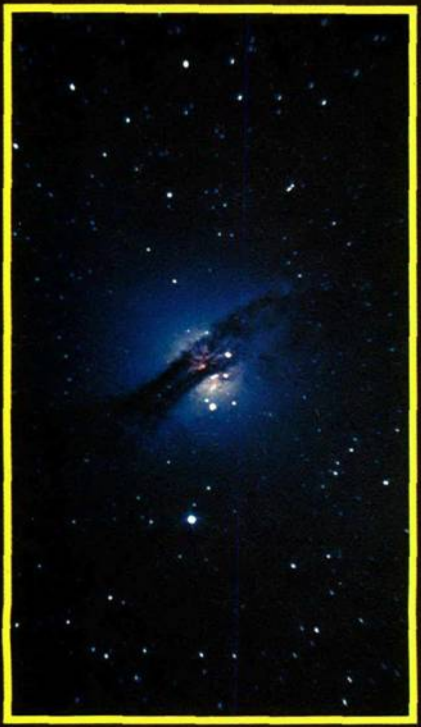
June sees Halley becoming more difficult to observe as the comet continues to fade and Sextans sinks into evening twilight by July. By mid-June, Halley will be equidistant from the Sun and Earth at 210 million miles. The comet's diminutive form will have faded to 10th magnitude, and the very sight of it will no longer be remarkable save for the knowledge that one is gazing at the solar system's most famous voyager.

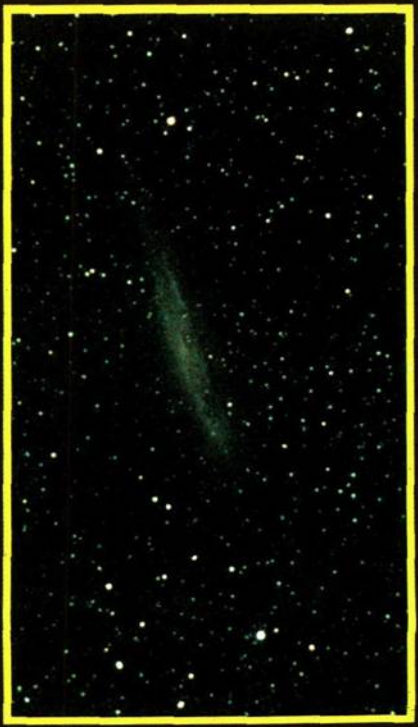
Although the comet will no longer be visually impressive, following Halley out during June will be a popular pastime for backyard stargazers. It will give each and every one of us a chance to reflect on our hopes and aspirations, our sightings, and our thoughts about the solar system, the Galaxy, and the universe in which we live.

Halley's Comet didn't provide backyard astronomers with an awesome spectacle, but it nevertheless holds a special place in the hearts and minds of backyard observers everywhere. I, for one, enjoyed viewing the comet as much or more than any other single experience I've had in the hobby of amateur astronomy. Goodbye, Halley.

— David J. Eicher



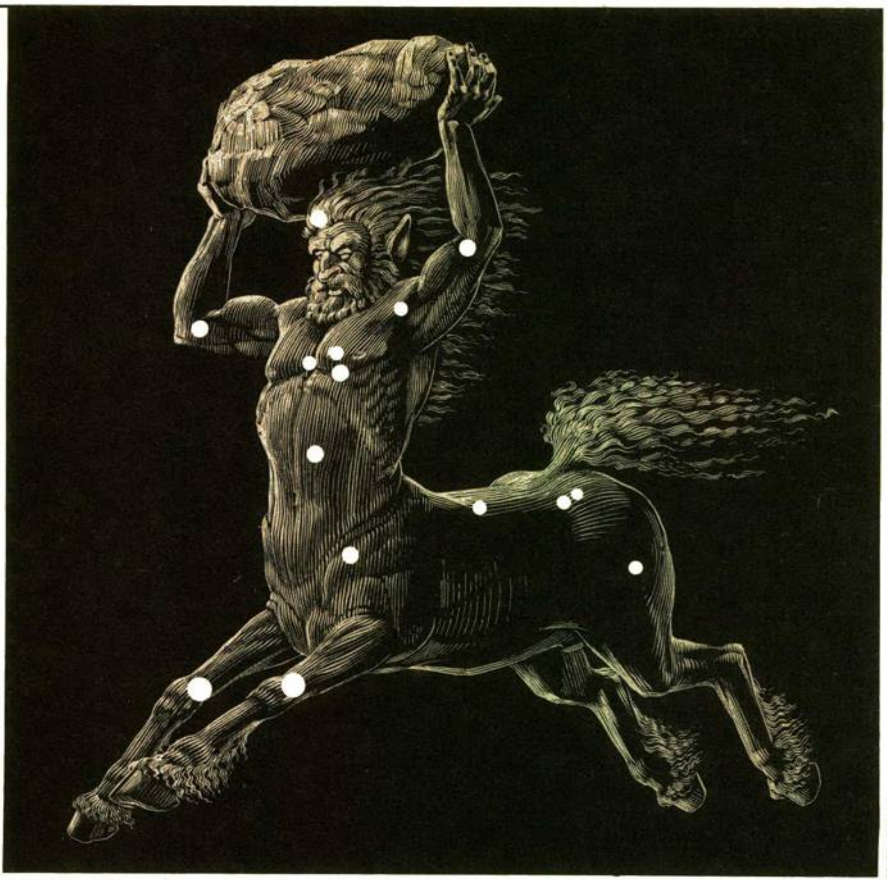




Above: Omega Centauri, the finest globular star cluster in the sky, is visible to the naked eye as a small fuzzy ''star'' and is apparent in 3-inch telescopes as a mass of partially resolved stars. Photo by Jack Newton. Far left: The galaxy NGC-5128, located some 4° north of Omega, is one of the sky's best active galaxies. Small scopes show its dust lane separating two enormous lobes of fuzzy light. Photo by Jack B. Marling. Left: NGC-4945 is a fine edge-on barred spiral that is visible in binoculars. Photo by Jim Barclay.

Centaurus

Cen
Centauri



Keith Ward

Lying between Hydra — rich in galaxies — and Crux — rich in Milky Way clusters and nebulae — is the large and bright constellation **Centaurus** the Centaur. Because it is located on the fringe of the southern Milky Way, this group of stars contains a diverse collection of both clusters and nebulae belonging to our home galaxy. It also contains a number of distant spiral and elliptical galaxies that are bright enough to shine through the Milky Way's blanket of obscuring dust. Particularly notable are the globular cluster Omega (ω) Centauri — the brightest such object in the sky — and the bright active galaxy NGC-5128. Centaurus also contains Alpha (α) Centauri, the closest star system to our Sun.

Several of Centaurus' best galaxies lie in the constellation's central region. One of these is **NGC-4945**, a large, edge-on barred spiral that is visible as a streak of wispy light even in a pair of large binoculars. To find NGC-4945, first locate the 5th-magnitude bluish star Xi^1 (ξ^1) Centauri and then move your telescope 30′ northeast. This galaxy has a blue magnitude of 9.5 (implying its V magnitude is a half magnitude or more brighter); its dimensions are an extensive 20.0′ x 4.5′. In comparison, the well-observed edge-on galaxy NGC-4565 in Coma Berenices shines at magnitude 9.6 and covers only 16.2′ x 2.8′ of sky.

NGC-4945 appears dramatically different through telescopes as the aperture increases. Large binoculars and small scopes show only a sliver of gray light spanning some one-third of the Moon's diameter. A 10-inch telescope reveals a tiny knot of a nucleus surrounded by the faint, mottled haze of the galaxy's spiral arms. An even larger scope, one in the 16-inch or bigger class, displays NGC-4945 as a highly inclined dinner plate some 15′ long with a bright stellar nucleus.

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

Just 4° northeast of NGC-4945 is the popular, impressively bright globular cluster **Omega** (ω) **Centauri**, which is catalogued by J.L.E. Dreyer as NGC-5139. This cluster is so large and bright that early astronomers believed it was a star. As early as A.D. 140, Ptolemy included Omega in his star catalogue, the *Almagest*. In the seventeenth century, Johannes Bayer designated it one of the brightest "stars" in Centaurus. The first to recognize Omega as a star *cluster* was Edmond Halley in 1677.

To the naked eye, Omega appears as a hazy star or a comet without a tail, but telescopes show an oblate disk with rich outlying sections that cover as much sky as the Full Moon (its total visual diameter is 36′). Individual stars belonging to the cluster are observed out to 90′, or some 150 parsecs.

Telescopically, Omega Centauri is far and away the most dazzling globular. A 3-inch scope shows a large, fuzzy disk appearing mottled on its edges whereas a 6-inch scope under dark skies resolves the cluster into myriad stellar points. The best view of Omega comes with 10-inch or larger scopes at low power: the huge globular literally overflows the field of view with thousands of resolved, yellow-white, crisp points of light.

About 4° due north of Omega is **NGC-5128**, one of the finest examples of an active galaxy. In large finderscopes and binoculars it appears as a matched pair of semicircles that are separated by a dark gap, which is a broad equatorial dust band. The galaxy measures 18.2′ x 14.5′ across and shines at magnitude 7.0. It is close enough at 4 megaparsecs that large backyard telescopes show structural detail in NGC-5128's halo and dust lane.

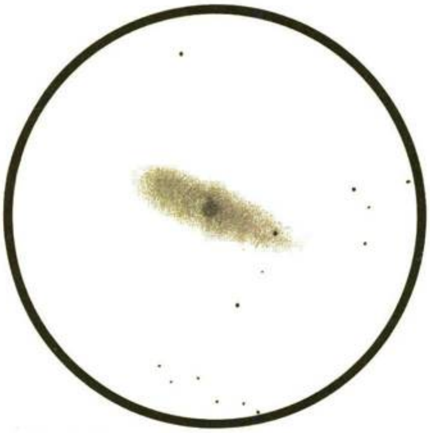
A 16-inch telescope at 100x shows NGC-5128 as a bright circular patch of fuzzy gray light, intensely bright toward the middle and bisected by the dust lane, which is thicker and twisted at opposite sides of the galaxy's edge. The bright edges of the dust lane show tiny clumps and knots of nebulosity, and an extensive network of very faint nebulosity lies inside the dark lane. This material, seen projected against the dust band, is composed of gigantic chains of hot O- and B-type stars. These stars are grouped in associations and are visible only because they lie in front of the dust as viewed from our perspective.

Astronomers have classified NGC-5128 as an active galaxy, one demonstrating powerful, chaotic disruptions within its core. NGC-5128 is an intense emitter of radio energy, which is observed along two enormous lobes on either side of the galaxy's center. This suggests that NGC-5128, also known as Centaurus A (due to its radio emission), may house a supermassive black hole in its center.

About 5° southeast of Omega is the far

NGC-5102

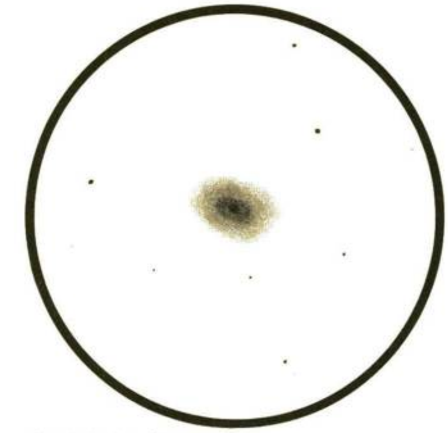
17.5-inch f/4.5
reflector
200x



Sketch by Steve Coe

NGC-5253

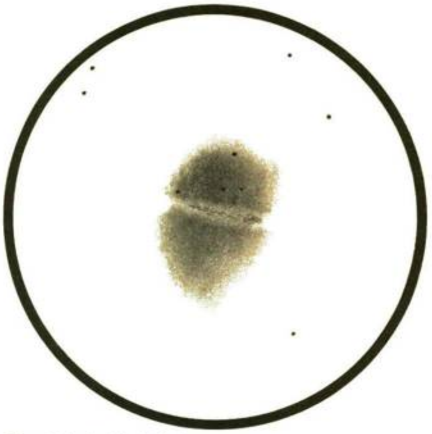
8-inch f/6
reflector
115x



Sketch by A.J. Crayon

NGC-5128

17.5-inch f/4.5
reflector
71x



Sketch by David J. Eicher

smaller globular **NGC-5286**, a pretty sight in medium- and large-aperture scopes. This cluster is a magnitude 7.5 object measuring some 9.1′ across. It lies within the same low-power field of view as the 5th-magnitude orange star M Centauri. Although it is large and bright, this cluster is considerably more difficult to resolve than Omega. A 6-incher at high power shows only the outer edges of the cluster resolved into a misty haze although the brilliant core remains an unresolved disk.

Three bright galaxies lie north of NGC-5128, the best of which is **NGC-5102**. This galaxy also lies near a bright star — 17′ northeast of the 3rd-magnitude double Iota (ι) Centauri — and is an impressive sight in most telescopes. Measuring 9.3′ x 3.5′ and glowing at magnitude 9.6, this spiral appears as a bright oval in 3-inch telescopes; with 6-inch scopes it becomes detailed, showing a condensed nucleus encapsulated inside a uniformly bright halo.

Some 4° northeast of Iota and NGC-5102 is the more diminutive galaxy **NGC-5161**, a faint spiral. This galaxy shines at magnitude 12.0 and covers 5.4′ x 2.3′ of sky, appearing as a bright knot of a nucleus surrounded by a large, faint, featureless haze.

A much brighter galaxy lies 3° to the northeast near the Hydra border: **NGC-5253**. This is a large, nearby, irregular galaxy spanning 4.0′ x 1.7′ and glowing at magnitude 10.6. A small telescope shows it as a smooth, featureless glow without central condensation whereas a 12- or 16-inch scope shows a markedly brighter center in an oval-shaped grayish nebulosity. Curiously, NGC-5253 has produced two brilliant 7th-magnitude supernovae within the past century: one in 1895 and another in 1972. NGC-5253 is a member of the Centaurus group of galaxies, which also includes M-83 in Hydra, NGC-5128, NGC-4945, and NGC-5102.

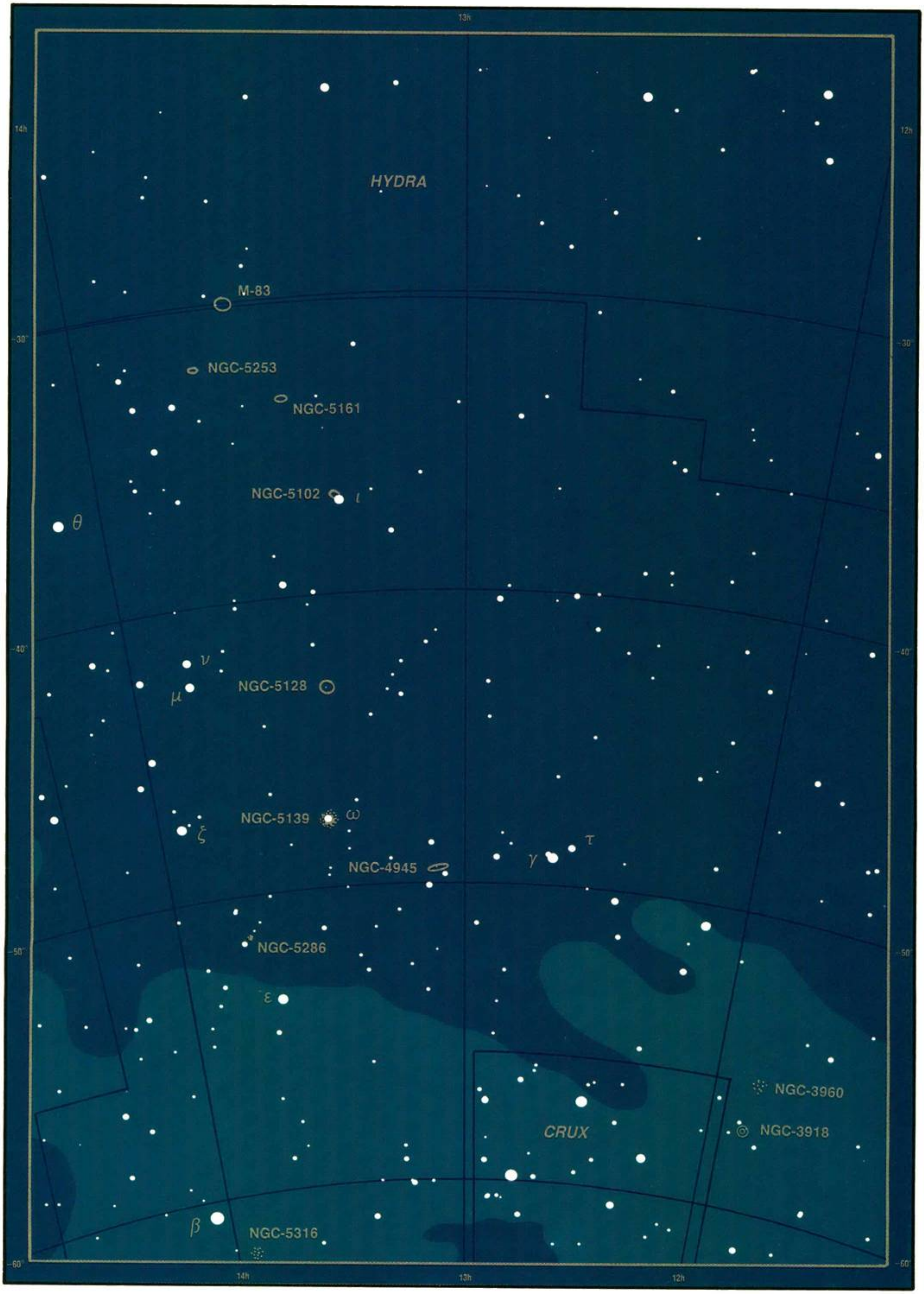
In the far southern reaches of Centaurus are two dazzlingly bright stars that are observational favorites. **Beta (β) Centauri**, the tenth brightest star in the sky, is a difficult double star for small scopes; its magnitude 0.6 and 3.8 stars are separated by a mere 1.3″ in p.a. 251° (1960). Beta Cen is some 150 parsecs distant, meaning that the component stars are 200 astronomical units — some 30 billion kilometers — apart. These two stars are truly luminous: the primary is some 10,000 times brighter than the Sun and the secondary is 440 times brighter than Sol.

Four-and-a-half degrees southeast of Beta is **Alpha (α) Centauri**. Lying a mere 1.33 parsecs distant, Alpha Cen is celebrated as the primary sun in the closest star system to our own. Sometimes called Rigel Kentaurus, Alpha Cen is the third brightest star in the sky (after Sirius and Canopus), shining at magnitude −0.4. It is bright enough to be visible during twilight, and is a pretty object to view as the sky darkens. The Alpha Cen system is a beautiful triple star composed of magnitude −0.04, 1.2, and 11.0 members with separations of 21.2″ (p.a. 212°) and 131′, respectively. The stars' colors create a pretty contrast: the primary is a dazzling yellow, the secondary a dull orange, and the distant companion (called Proxima) a weak burnt red. Proxima, incidentally, is a physical member of the system and is actually the closest to our solar system, hence its name.

Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	H
NGC-3766		⊙	11h 36.4m	−61°36′	5.1	10′	
NGC-3918		■	11h 50.3m	−57°11′	8.4	10″	
NGC-3960		⊙	11h 50.9m	−55°42′	9.0	6′	
NGC-4945		§B	13h 05.3m	−49°29′	9.5^{B}	20.0′x4.4′	SB(s)cd:
NGC-5102		§	13h 21.9m	−36°39′	9.6	9.3′x3.5′	$SA0^{-}$
NGC-5128		§L	13h 25.3m	−43°01′	7.0	18.2′x14.5′	S0pec
NGC-5139		●	13h 26.8m	−47°29′	3.7	36.3′	
NGC-5161		§	13h 29.1m	−33°09′	12.0	5.4′x2.3′	SA(s)c:
NGC-5253		#	13h 39.9m	−31°39′	10.6	4.0′x1.7′	I0pec
NGC-5286		●	13h 46.2m	−51°22′	7.5	9.1′	
NGC-5316		§	13h 53.9m	−61°52′	8.4	12′	
Beta (β)		★^{2}	14h 03.8m	−60°22′	0.6,3.8	1.3″	
Alpha (α)		★^{3}	14h 39.6m	−60°50′	0.0,1.3, 10.7	8.7″,132″	

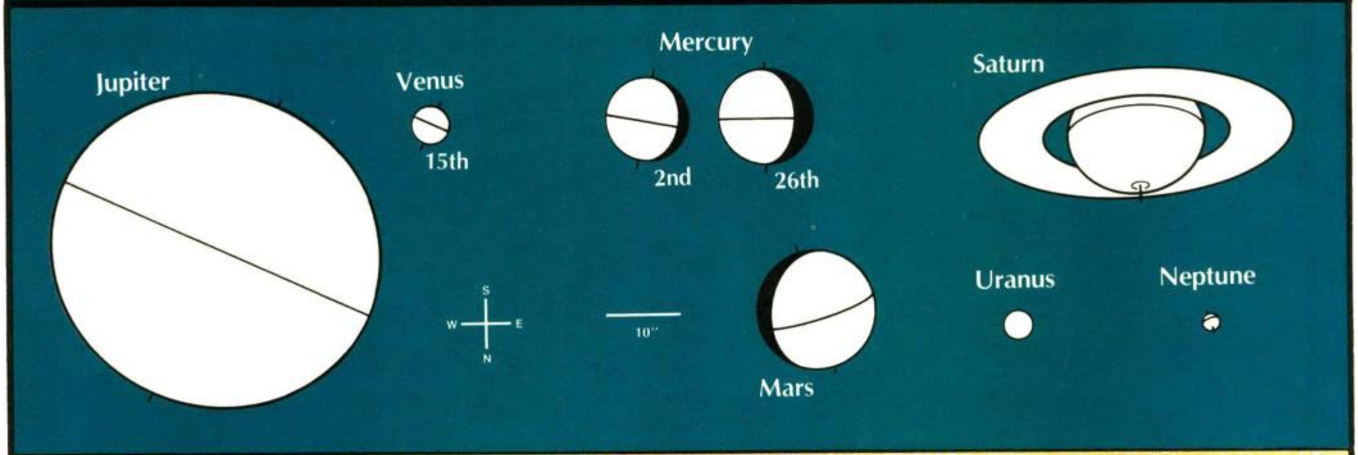
H = Hubble classification type for galaxies

★^{2}	*Double Star*
★^{3}	*Triple Star*
⊙	*Open Star Cluster*
●	*Globular Star Cluster*
■	*Planetary Nebula*
§	*Spiral Galaxy*
§B	*Barred Spiral Galaxy*
§L	*Lenticular Galaxy*
#	*Irregular Galaxy*


13h
14h
12h
HYDRA
M-83
-30°
NGC-5253
NGC-5161
NGC-5102
ι
θ
-40°
ν
μ
NGC-5128
NGC-5139
ω
ξ
τ
γ
NGC-4945
-50°
NGC-5286
ε
NGC-3960
CRUX
NGC-3918
β
NGC-5316
-60°
14h
13h
12h

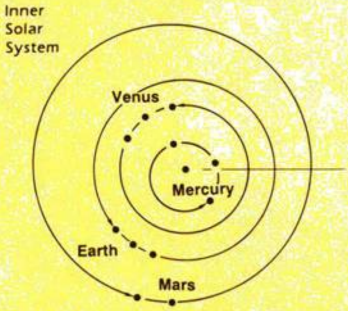
Planetary Data

May 1986

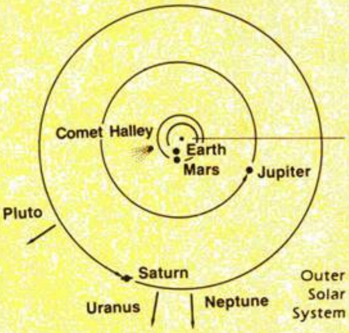


Jupiter
Venus
15th
Mercury
2nd
26th
Saturn
S
W
E
N
10″
Mars
Uranus
Neptune

		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Distance (AU) from: Sun	Longitude: Heliocentric	Longitude: Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.7	31.8′	—	1.01	—	—	40°20.4′	2h 32.4m	14°58.8′
		15	−26.7	31.7′	—	1.01	—	—	53°53.4′	3h 26.8m	18°47.6′
		31	−26.7	31.6′	—	1.01	—	—	69°16.2′	4h 31.1m	21°52.3′
Mercury	☿	1	−0.2	6.0″	72%	1.12	0.42	315°18.1′	19°04.3′	1h 14.1m	5°02.8′
		15	−1.3	5.2″	93%	1.29	0.34	15°05.8′	44°39.0′	2h 49.9m	15°16.2′
		31	−1.4	5.3″	92%	1.27	0.32	111°15.4′	78°58.9′	5h 11.7m	24°32.7′
Venus	♀	1	−3.9	11.1″	91%	1.50	0.72	101°07.3′	65°19.0′	4h 13.0m	21°51.4′
		15	−3.9	11.7″	87%	1.43	0.72	123°49.8′	82°16.6′	5h 21.0m	24°28.3′
		31	−4.0	12.5″	83%	1.34	0.72	149°50.1′	101°29.0′	6h 50.6m	24°41.4′
Mars	♂	10	−0.9	13.4″	91%	0.70	1.49	252°41.1′	288°19.2′	19h 20.3m	−23°44.3′
		20	−1.1	15.0″	92%	0.63	1.48	258°09.7′	290°58.1′	19h 32.1m	−23°53.2′
Jupiter	♃	15	−2.2	37.0″	99%	5.33	5.00	337°07.7′	347°56.6′	23h 17.3m	− 5°42.2′
Saturn	♄	15	0.1	18.4″	100%	9.00	9.99	246°00.9′	247°33.0′	16h 24.5m	−19°34.0′
Uranus	⛢	15	5.5	3.9″	100%	18.24	19.14	260°03.1′	261°37.0′	17h 23.6m	−23°15.9′
Neptune	♆	15	7.9	2.3″	100%	29.48	30.25	274°10.7′	275°36.7′	18h 24.4m	−22°13.1′
Pluto	♇	15	13.7	0.1″	100%	28.80	29.72	216°06.2′	215°40.6′	14h 35.8m	2°43.3′



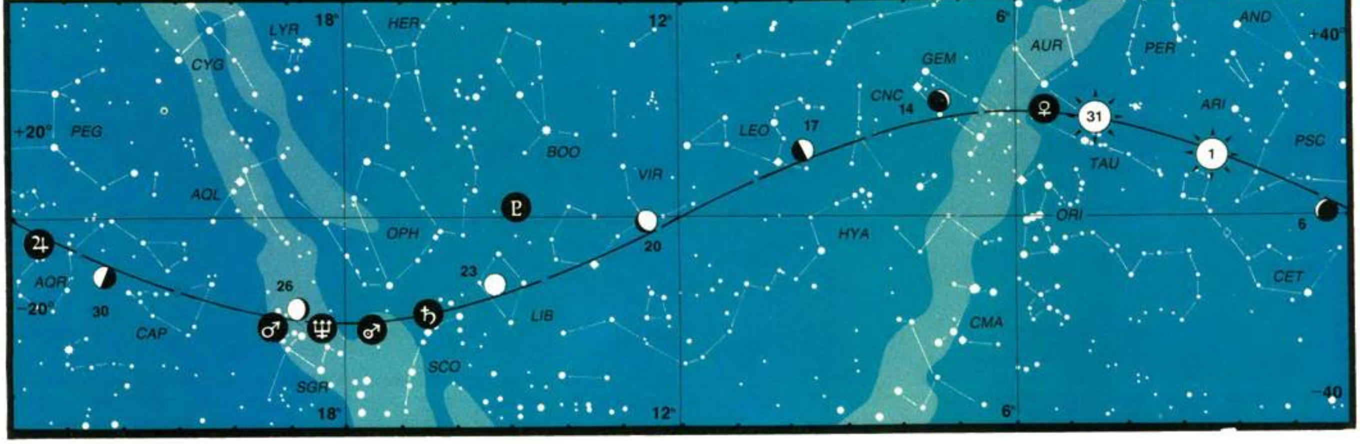
Inner
Solar
System
Venus
Mercury
Earth
Mars



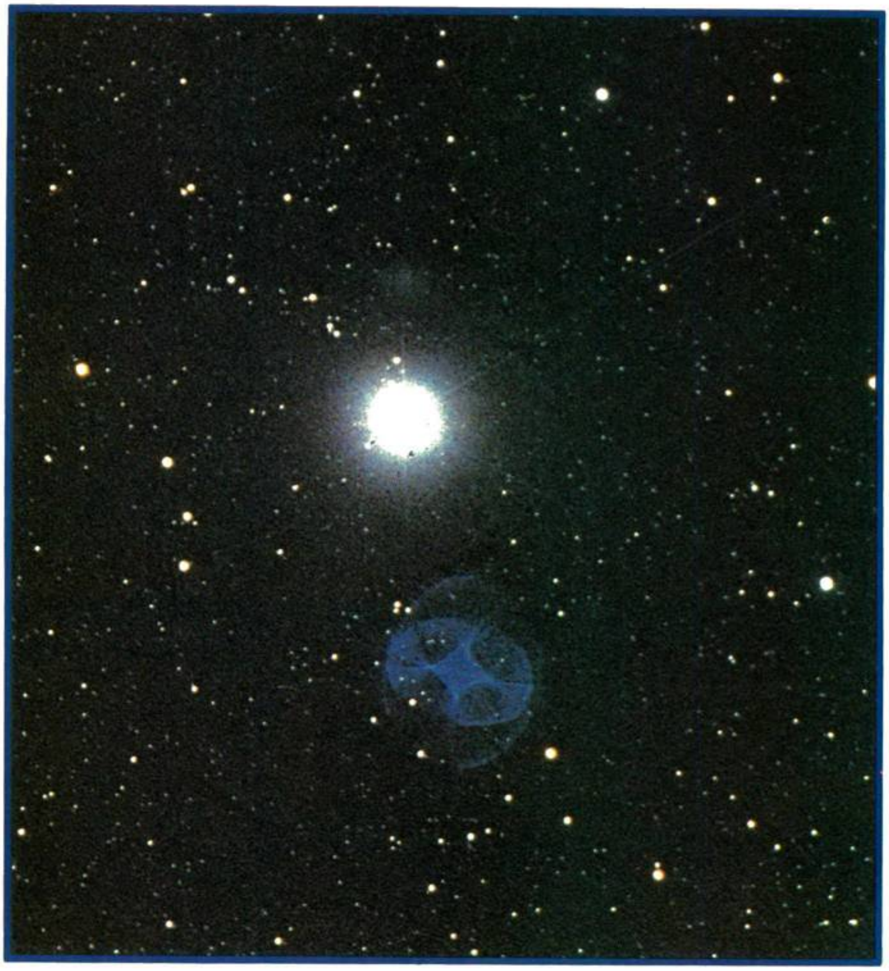
Comet Halley
Earth
Mars
Jupiter
Pluto
Saturn
Uranus
Neptune
Outer
Solar
System

Moon Data

Last Quarter. . . . . .May 1 at 3h22m
New Moon. . . . . .May 8 at 22h10m
First Quarter. . . . . .May 17 at 1h00m
Full Moon. . . . . .May 23 at 20h45m
Last Quarter. . . . . .May 30 at 12h55m
New Moon. . . . . .June 7 at 14h 00m
Apogee: May 10 at 22h40m. . .406,329 km.
Perigee: May 24 at 3h01m. . . .357,097 km.



18°
12°
6°
+40°
+20°
−20°
−40
LYR
HER
CYG
PEG
AQL
BOO
VIR
OPH
LEO
CNC
GEM
AUR
PER
AND
ARI
PSC
TAU
ORI
HYA
CET
AQR
CAP
SGR
SCO
LIB
CMA
14
17
31
1
6
20
23
26
30



The bright star in the center of this photo is well-known Regulus, the yellowish beacon of Leo the Lion. Not so well known is the fuzzy patch of bluish light just 20' north called Leo I. It is a nearby dwarf irregular galaxy residing in our Local Group. Although relatively close, Leo I is not easy to observe: its light is so spread out that the galaxy is difficult to see with anything less than a 20-inch telescope. (The weird-shaped object below Regulus is a reflection of the bright star caused by the telescope's optical system.) Photo by Mace Hooley.

Mercury

Mercury is at superior conjunction with the Sun on May 23 at 1h UT. It is out of sight all month, but the upcoming evening apparition in June will be one of the year's best.

Venus

Prominent in the evening sky, Venus makes a natural target for telescope users. It appears as a tiny gibbous "moon" about 12" across, but the resemblance stops there because Venus' seamless cloud deck displays no visible features. Since the planet is still quite low as the sky darkens, try observing early in twilight. Venus will then appear higher in the sky and viewing will suffer less from atmospheric distortion.

Moon

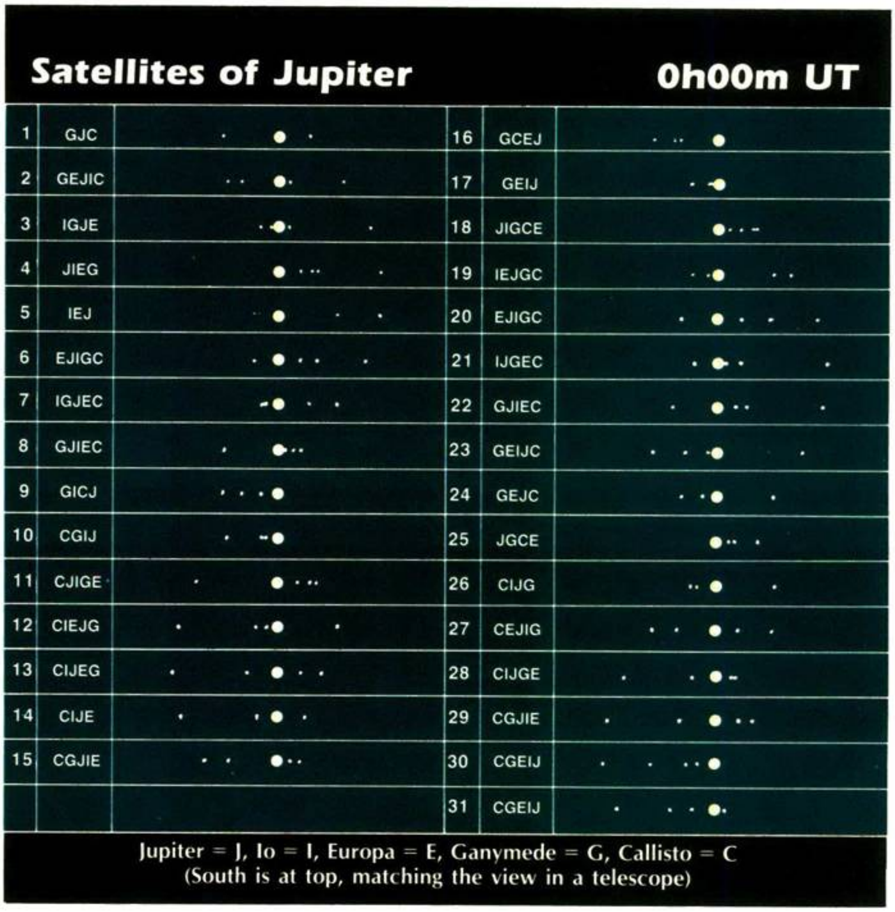
The Moon will occult the bright double star Antares in the constellation Scorpius on May 24. The event is visible anywhere north of a line that runs southeastward from British Columbia across western Montana, central Wyoming, and north-central Kansas. The limit line continues eastward across central Missouri and southern Illinois, and then turns northeastward through Indiana, Ohio, western Pennsylvania, central New York, and northern Vermont. (If you view from south of this line, the Moon will not occult Antares but will instead pass north of the star.)

The Moon's southern limb will cover Antares beginning about 7h40m UT on the western end and 8h45m UT on the eastern end of the viewing area. The occultation will last half an hour in the west, diminishing to twenty minutes in the east.

Since the Moon will be nearly Full, use medium to high powers on your telescope or you may lose sight of Antares as it approaches the brightly lit mountains on the Moon's limb. The Antares system contains a 1.2-magnitude red giant primary star and a 5.4-magnitude secondary separated by 2.8" in p.a. 273°. Many observers find the secondary looks distinctly greenish compared to the strong ruddy tint of the primary. The primary's great brilliance and the nearby Moon will make the secondary difficult to spot.

Mars

Increasing in apparent size and brightness, Mars is drawing steadily closer to opposition as July approaches. Over the



Satellites of Jupiter **0h00m UT**

Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)

Right: Edwin Hirsch's photograph of the Sun in Hα light wins May's "Best Astrophoto" award of $100. Left: When this photo of Saturn was made on January 7, 1981, the planet's rings were tilted much closer to edge-on than they now appear. Photo by Donald C. Parker using a 12.5-inch Newtonian at f/96, a 7-second exposure, and Ektachrome 200 film.

course of May, the planet's distance from Earth shrinks from 115 million kilometers to 83 million. As a result, the Martian disk enlarges from 12.0″ to 17.0″ across. Mars is presently a morning object, rising well before the Sun and crossing the meridian late in morning twilight.

Minor Planets

1 Ceres (magnitude 7.7) is moving southeastward in Leo about 30 minutes of right ascension west of 2.6-magnitude Delta (δ) Leonis. Its positions:

1st: 10h 41m 42s, 22° 53.9′
10th: 10h 45m 08s, 21° 46.8′
20th: 10h 50m 58s, 20° 22.4′
30th: 10h 58m 36s, 18° 49.9′

Ceres sets around 3:30 a.m. local time on the 15th.

2 Pallas (8.7) has a northeastward motion that carries it within 2° of 1st-magnitude Procyon in Canis Minor. Its positions:

1st: 7h 20m 03s, 1° 50.3′
10th: 7h 37m 05s, 3° 23.3′
20th: 7h 56m 35s, 4° 46.8′
30th: 8h 16m 28s, 5° 50.8′

Pallas sets about 11:30 p.m. local time on the 15th.

3 Juno (10.4) is at opposition on May 30 in the constellation Ophiuchus. For a day or two around the 15th, Juno almost forms a right triangle with the globular clusters M-10 and M-12. Its positions:

1st: 17h 02m 06s, −5° 45.4′
10th: 16h 56m 47s, −5° 02.8′
20th: 16h 29m 48s, −4° 21.8′
30th: 16h 41m 15s, −3° 50.3′

Juno is visible all night long.

4 Vesta (7.9) is moving eastward in northeastern Aquarius. Its positions:

1st: 23h 22m 59s, −8° 26.2′
10th: 23h 37m 54s, −7° 12.5′
20th: 23h 53m 46s, −5° 55.5′
30th: 0h 08m 50s, −4° 45.2′

Vesta rises around 3:30 a.m. local time at mid-month.

40 Harmonia (10.8) is moving retrograde in central Libra. Its positions:

1st: 15h 38m 23s, −14° 06.2′
10th: 15h 29m 34s, −13° 43.1′
20th: 15h 19m 03s, −13° 20.5′
30th: 15h 09m 15s, −13° 03.8′

Reaching opposition on May 14, Harmonia is visible all night long.

To locate a minor planet, plot its dated positions (given for 0h UT) lightly in pencil on a good star atlas (*Sky Atlas 2000.0*, for example) and sketch a smooth curve linking the points. Then observe the starfield at low magnification and photograph or plot by hand what you see. Check the field a night or two later; the "star" that has moved is it. (All minor planet coordinates are for the epoch 2000.0.)

Jupiter

Rising a few hours before the Sun, Jupiter is conspicuous in the southeast during morning twilight. Measuring some 37″ across its equator (35″ over the poles), Jupiter's oval disk offers a wealth of detail for patient observers. Most obvious are two dark bands that span the planet's girth; these are the north and south equatorial belts. (The southern one often has two components; can you discern them?)

The famous Great Red Spot, though not as prominent as its name suggests, lies just south of the south equatorial belt. If you can't see it, don't worry — the Red Spot may not be on the hemisphere that is visible at the time you are viewing. But don't give up on it, however; look for the Red Spot again the following morning. By viewing at the same time each day, you'll see Jupiter's central meridian situated about 160° away from its location of the previous day. A few mornings' worth of observing should uncover the Red Spot for you.

Saturn

Reaching opposition to the Sun around 1h UT on May 28, Saturn is very well placed for viewing this month. The planet's disk spans 18.4″ at the equator and 16.8″ at the polar regions; the rings spread 41.7″ across. The northern surface of Saturn's rings is tipped 25° to our line of sight.

Titan, which circles Saturn once every 15d 23h, is one of the largest moons in the solar system and is easy to see in all telescopes. Titan lies about four ring-diameters to the west of Saturn on the nights of May 4/5 and 20/21 and will lie east of Saturn on May 12/13 and 28/29.

Uranus

The best way to locate Uranus is to center the 3.3-magnitude star Theta (θ) Ophiuchi in a low-power eyepiece and sweep north about 2°. Uranus looks distinctly nonstellar: it has a 3.9″ greenish disk and a magnitude of 5.5.

Neptune

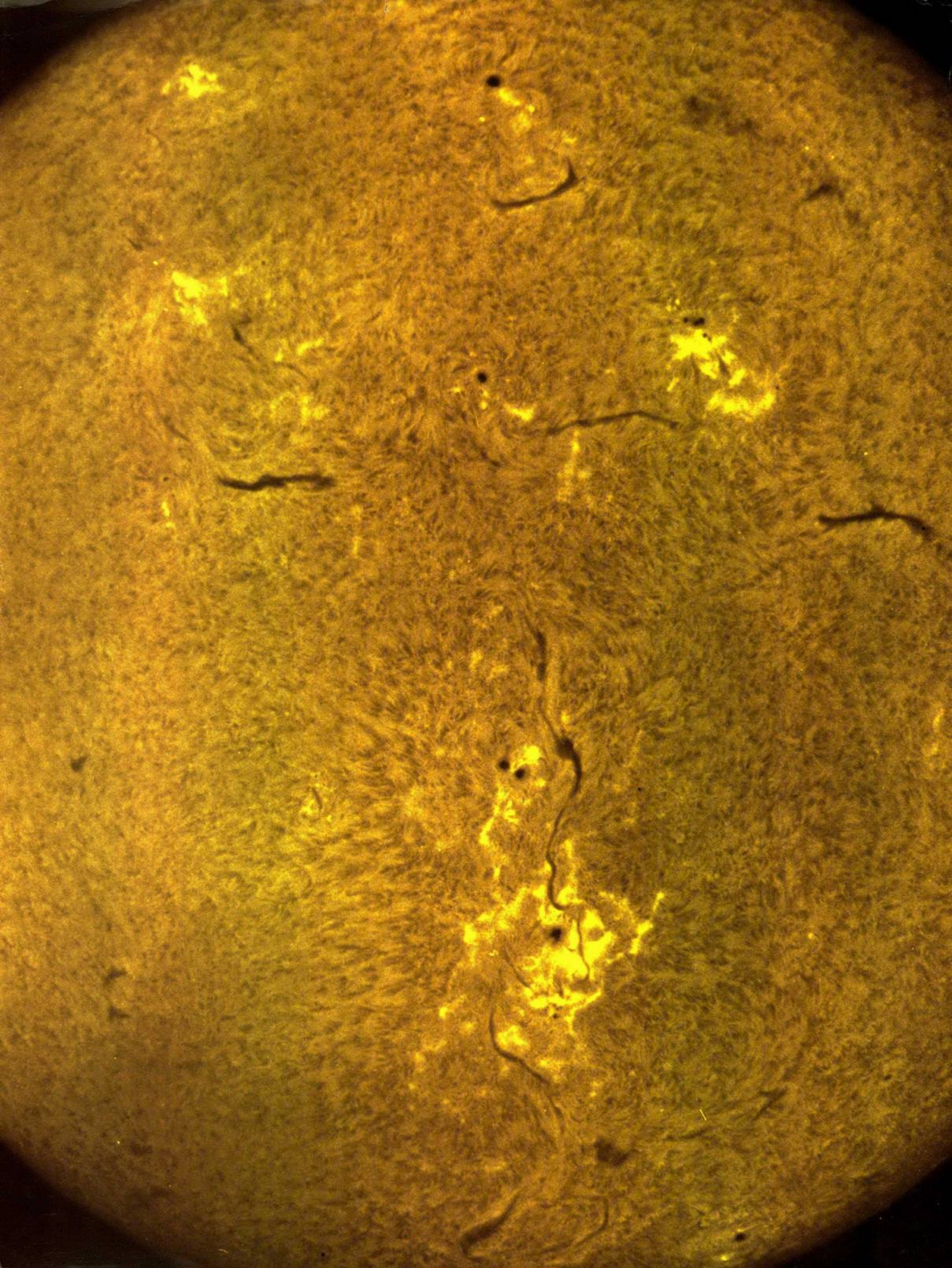
Neptune lies 3° north and about 4 minutes of right ascension west of 2.8-magnitude Lambda (λ) Sagittarii, the star at the top of the "Teapot's" lid. (See the finder chart on page 107 of the January 1986 issue.) At magnitude 7.9, Neptune has a 2.3″ grayish disk.

Meteors

Derived from Comet Halley, the Eta (η) Aquarid meteor shower offers moderately good viewing prospects this year. The Aquarids reach a broad peak of activity on May 4 when the Moon is close to New. The radiant lies near the Water Jar asterism in Aquarius and rises around 3 a.m. local time on the 4th. The usual rates are 15 to 20 meteors per hour, but Halley's proximity should boost activity substantially.

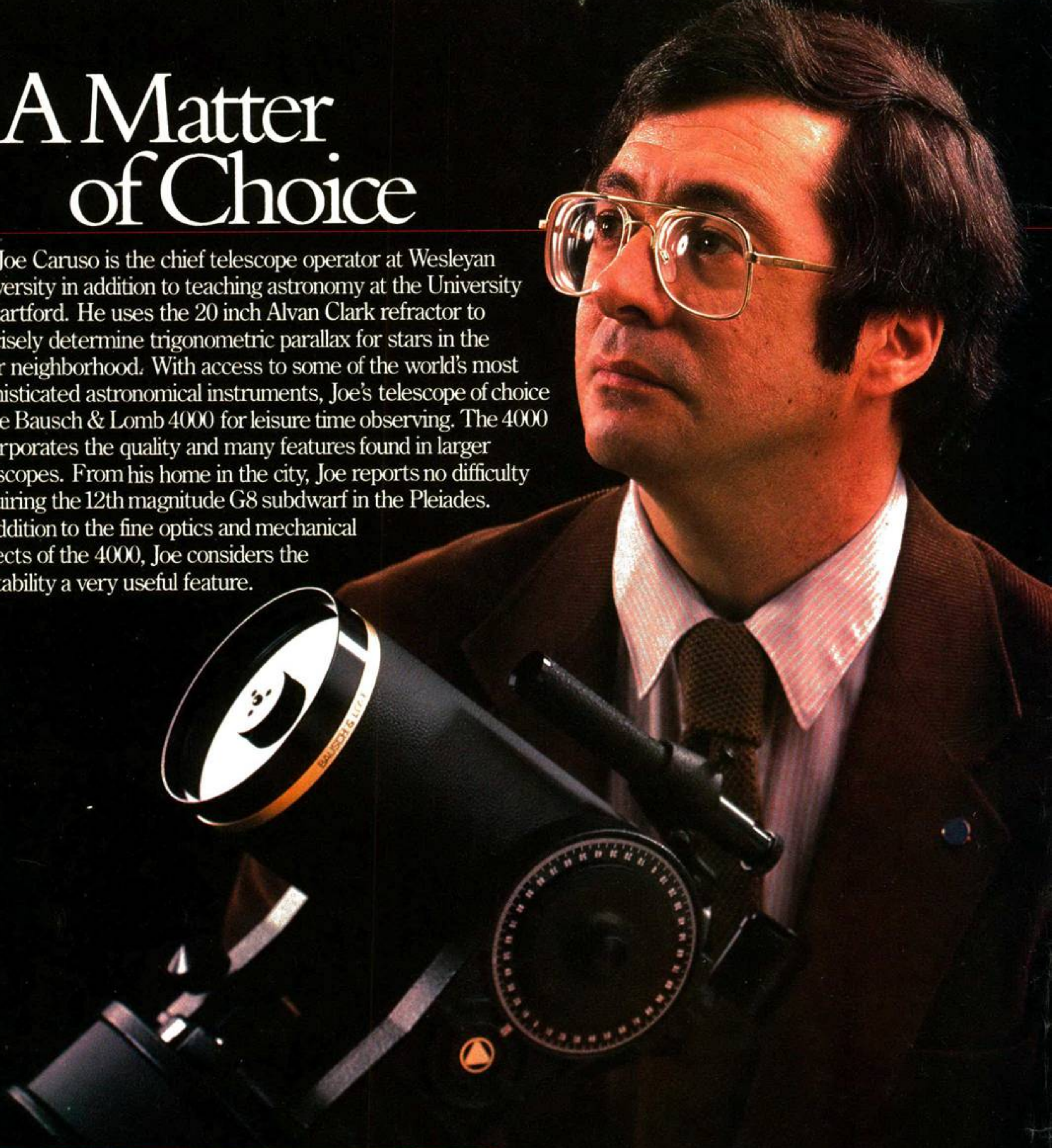
Comet Halley

For the general public, Halley has been "gone" for a month or more. The comet will be easily visible in small telescopes, however, for some time yet. On May 1, it will lie just 30′ west of Alpha (α) Crateris, a 4.1-magnitude star. On the 4th, it will pass even closer to the west of 3.1-magnitude Nu (ν) Hydrae. For detailed observing information, see "Following Halley Out" on page 90.



A Matter of Choice

Joe Caruso is the chief telescope operator at Wesleyan University in addition to teaching astronomy at the University of Hartford. He uses the 20 inch Alvan Clark refractor to precisely determine trigonometric parallax for stars in the solar neighborhood. With access to some of the world's most sophisticated astronomical instruments, Joe's telescope of choice is the Bausch & Lomb 4000 for leisure time observing. The 4000 incorporates the quality and many features found in larger telescopes. From his home in the city, Joe reports no difficulty acquiring the 12th magnitude G8 subdwarf in the Pleiades. In addition to the fine optics and mechanical aspects of the 4000, Joe considers the portability a very useful feature.



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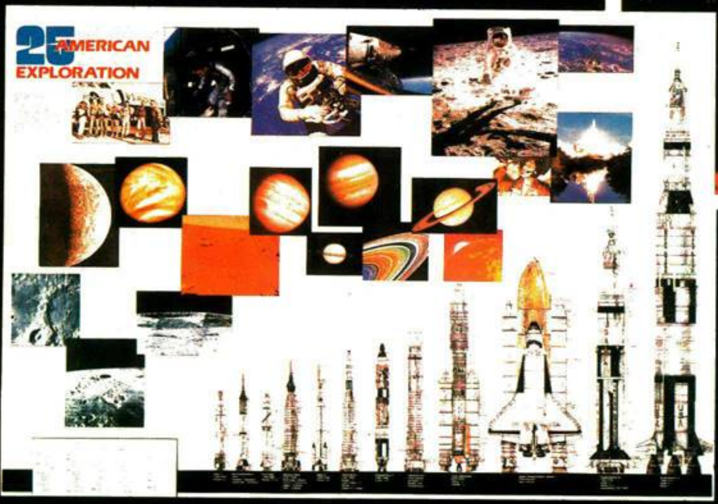
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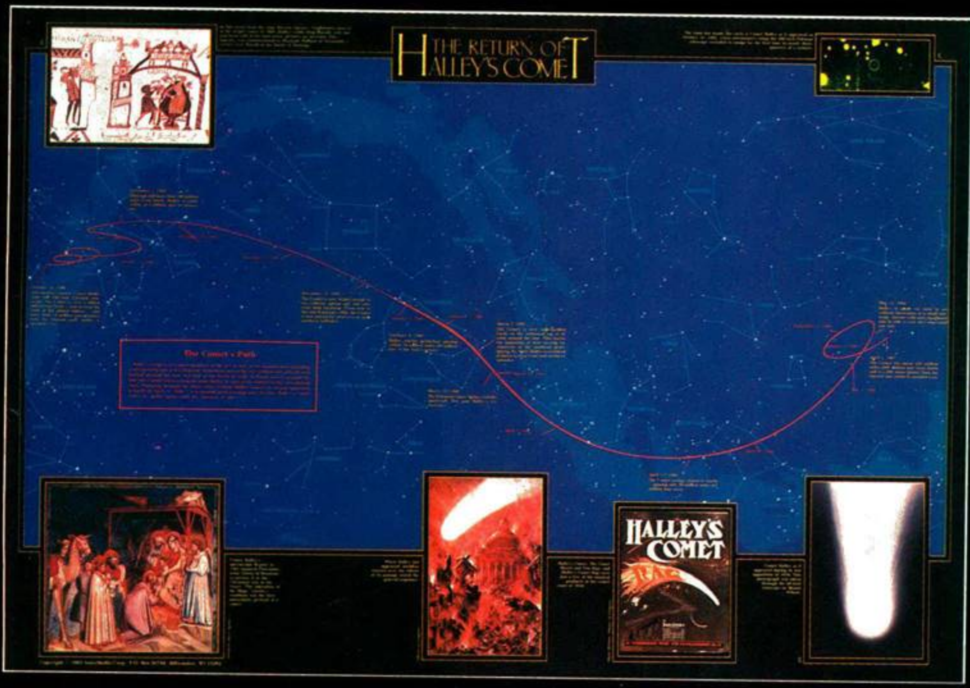
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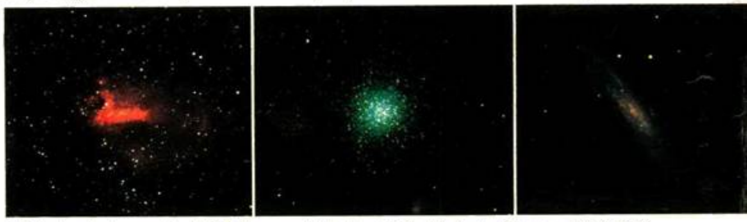

C8 Astrophotographs: M-17, Omega Nebula; M-13, Globular Cluster; NGC-253.

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